Essays in International Economics

by

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Abstract

This dissertation analyzes how trade openness affects a country's set of policy instruments in times of economic crises. Exploiting variations across Estonian firms trading with different markets, the first chapter shows that firms' output substantially reacts to exchange rate movements in both their export and import market. Still, the estimated trade elasticity implies that monetary policy is equally effective in closed and open economies because traded and non-traded sectors expand by equal amounts following a monetary expansion. The second chapter shifts the focus on fiscal policy and examines the effects of austerity on economic performance since the Great Recession. In a panel of 29 mostly European countries it shows that reductions in government purchases larger than that implied by reduced-form forecasting regressions are statistically associated with lower real per GDP and lower inflation. The implied multiplier is greater than 1, which shows that fiscal policy has strong domestic effects even in small and open economies. A multi-country DSGE model calibrated to the European economies replicates the qualitative features of the observed patterns, but falls short quantitatively of the multiplier on government purchases. The last chapter analyzes macroeconomic policies to promote mergers and acquisitions (M&As). A tractable model is developed to study the role of M&As during financial crises characterized by tighter bank lending standards. It suggests that cross-border M&As can be particularly beneficial because they help to tap foreign capital markets, while domestic M&As have a much smaller effect because domestic acquirers themselves face liquidity constraints. Being open can therefore be a virtue during times of tight domestic credit markets.

Introduction

How does an economy's openness affect its policy options in the face of economic crises? This topic has regained new interest in recent years as countries in Europe experienced their worst recession for several decades in 2008/09. After many years of ever-closer integration policy makers now face the constraints that this same process of integration puts on their set of policy instruments. Whereas closed economies can freely conduct monetary and fiscal policy to counteract recessions, open economies are often restrained in their policy choices, either because they are part of a monetary union or the effects of fiscal policy simply leaks to neighboring countries. That being said, open economies might also have additional policy instruments at their disposal, e.g. if, in times of domestic financial crises, they are able to 'tap' other countries' capital.

This dissertation sheds light on this multi-faceted topic by analyzing the effects of three policy instruments in open economies: monetary and exchange rate policy in a small open economy, fiscal policy in a set of integrated economies, and policies allowing for cross-border mergers and acquisitions during financial crises.

The first chapter asks how exchange rate movements affect an economy's performance. It is motivated by the experience of Estonia and its neighboring Baltic countries that suffered output losses of 15% or more during the Great Recession, but decided not to abandon their currency peg to the euro. In this context, an open question is whether a currency devaluation would have helped these economies. The idea that a currency devaluation would help exporting firms by making their products more competitive on international markets is intuitive, but lacks thorough empirical evidence. This chapter provides such empirical evidence by exploiting a rich dataset of

Estonian firms. Identification comes from comparing the production of firms that operate in the same industry, but export to different markets and are therefore subject to different exchange rate shocks. The empirical evidence presented in the chapter suggests that a 1 percent exchange-rate induced decrease in a firm's output price raises its revenue by 1.3 percent. Similarly, the data also supports the view that importing firms are hurt by an exchange rate depreciation, although the effect is somewhat smaller: a 1 percent increase in marginal costs through higher import costs lowers their revenue by 0.5 percent. To quantitatively assess the economy-wide impact of an (across-the-bord) exchange rate devaluation, a New Keynesian small open economy model is developed. A version of this model that is calibrated to the empirical results suggests that the expansionary effects of a devaluation (modeled as an expansion of the money supply) dominate, with a 10 percent devaluation raising GDP by more than 5 percent upon impact. Part of this relatively large effect is driven by the expansion of firms in the non-traded sector as firms and consumers switch from imports to domestic substitutes. This expansion of the non-traded sector also explains why the model has very similar GDP predictions for varying degrees of trade openness. This result that expansionary monetary policy seems equally effective in fairly closed and more open economies, however, critically hinges on the estimated trade elasticity, with higher trade elasticities implying stronger effects in more open economies.

The second chapter analyzes to what extent fiscal policy can account for the cross-country differences in economic performance in Europe since 2010. Motivated by a popular view that austerity policies have contributed to the slow European recovery, it empirically analyzes this claim by constructing measures of austerity and relating them to countries' economic performance. Austerity is measured as the (log) difference between observed government purchases (or revenue) and their predicted value. The results support the view that austerity in government purchases - a reduction in government purchases that is larger than that implied by reducted-form forecasting regressions - is statistically associated with below forecast GDP and inflation. The implied GDP multiplier on government purchases is around 1.3. Austerity in form of higher government revenue, however, is not associated with weaker economic performance. In a second step, a multi-country New Keyneasian DSGE model is developed to compare the observed empirical relationships and model predictions. Feeding in the empirically observed government purchases shocks, the model predicts responses of macroeconomic variables that are broadly consistent with those seen in the data. But quantitatively, the model underestimates the multplier on government purchases (0.75 vs. 1.3). The low multiplier in the model is partially a result of European economies being particularly open, so that the effects of government purchases leak out to neighboring countries.

The last chapter focuses on macroeconomic policies that promote (cross-border) mergers and acquisitions (M&As). Whereas fiscal policy and monetary policy (if the trade elasticity is low enough) are less effective in open economies, being open might turn out to be a virtue in the market for corporate control. The chapter is motivated by the financial crises in emerging markets throughout the 1990s and asks to what extent a flourishing M&A market can substitute for a distressed banking sector. To answer this question, a model of M&As is developed. M&As are undertaken by either domestic or foreign firms, but domestic acquirers are assumed to face the same borrowing constraints as their potential targets. This one-dimensional difference between (potentially constrained) domestic and (unconstrained) foreign acquirers leads to distinct predictions in terms of acquired shares and divestiture rates across acquirers and during financial crises vs. normal times. These predictions are in line with the empirical evidence presented in the chapter. The model is then used to analyze how M&As affect an economy's overall performance during financial crises. In a model without any M&As, financial crises do not affect the average productivity of operating firms, simply because it is assumed that financial constraints tighten for all firms symmetrically. Allowing for foreign M&As dramatically alters this prediction and leads to a positive cleansing effect. Fixed costs of acquisitions imply that foreign firms acquire (and save from exit) only firms that are above a certain level of productivity, and this 'cream skimming' effect becomes particularly strong during financial crises. Allowing for domestic M&As also leads to a positive cleansing effect, but this effect is quantitatively negligible. Being themselves constrained, domestic firms are unable to save high-productivity firms that are illiquid. Overall, the market for corporate control can therefore substitute for a distressed banking sector, but this is much more true if foreign capital can be tapped.

Chapter I

Are Devaluations Expansionary? - Firm-Level Evidence from Estonia

1 Introduction

During the global financial crisis the economies in Europe contracted sharply and many of them had not recovered by the end of 2014. Yet, despite output losses of 15% or more, no country in Europe left the Eurozone or abandonned its currency peg to the euro. An open question is whether a currency devaluation would have actually improved economic performance and sped up the recovery. In fact, this question was raised in the Baltic countries during the recession and more recently, has attracted renewed attention due to a possible 'Grexit', an exit of Greece from the Eurozone. This paper utilizes a firm-level database to assess the effect of exchange rate fluctuations on economic performance and builds a New Keynesian open economy model to analyze the general equilibrium effects of a currency devaluation.

A widely accepted view in the literature is that exchange rate depreciations are expansionary by making exports more competitive (see e.g. Eichengreen and Sachs, 1985). This effect, however, is empirically hard to identify for at least three reasons: First, large currency devaluations are often accompanied by other major macroeconomic changes that affect an economy's overall performance, as was observed in South East Asia in 1997 and Argentina in 2002. Second, exchange rate depreciations entail an increase in import costs as well as an increasing debt burden for firms that borrowed in foreign currency. Both effects might hinder economic expansion. Third, foreign demand for export goods following a depreciation will only increase if foreign consumers see a fall in the price. If prices are sticky and invoiced in the consumer's currency, such a price decline may not occur. Establishing the link between nominal exchange rate fluctuations and real economic performance has therefore proven to be a difficult task.

To address these three identification issues, I make use of an Estonian firm-level database to exploit variations in exchange rate movements across firms exporting to and importing from different markets. First, by comparing the production of firms in the same industry exporting to different markets, I can control for macroeconomic or industry-level changes that differentially impact economic performance. Second, I observe a firm's imports by its source and can therefore control for import cost shocks that might be systematically correlated with a firm's export exchange rates. In addition, Estonia's firms overwhelmingly borrowed in either euros or Estonian kroons, limiting the impact of exchange rate changes on their debt burden.[1] Third, I control for the invoicing currency of a firm's trade transactions. I show that under sticky prices, the relevant effective exchange rate for a firm is a trade-weighted average of both bilateral exchange rates across all its markets and the exchange rates of its invoicing currencies. Changes in these exchange rates can be interpreted as exogenous changes in a firm's output price index or a firm's marginal cost of production. Using these firm-level effective exchange rates as my independent variables, I measure their impact on various performance measures at the firm level, including revenue, hours worked and intermediate inputs.

I find strong effects of nominal exchange rate movements on firm performance. Overall, firms facing depreciations in their effective export exchange rate expand, whereas firms seeing their effective import exchange rate depreciate contract. A depreciation of a firm's effective export

[1] The Estonian kroon was pegged to the euro till 2011, when Estonia adopted the euro. In 2007, the middle of my sample, the stock of loans to non-financial corporations was 74 percent in euros and 21 percent in Estonian kroons, according to Estonia's central bank, Eesti Pank (http://statistika.eestipank.ee/?lng=en#treeMenu/FINANTSSEKTOR, 3.3.1. Stock of loans by customer group, residence, currency and maturity)

exchange rate equivalent to a 1 percent increase in its output price increases a firm's revenue in the same year by 1.3 (all firms) to 2 percent (large firms) and its employment by 0.5 to 0.6 percent. A depreciation of a firm's effective import exchange rate of a size equivalent to a 1 percent increase in marginal cost reduces revenue by 0.5 to 1.5 percent and employment by 0.6 to 1.4 percent.

Taken together, these results predict that a common devaluation of the Estonian kroon in both the export and import market is expansionary for revenue, but slightly contractionary for hours worked, all else being equal. The net effect is relatively modest because a large share of Estonia's trade is invoiced in foreign currency, which reduces the size of the export expansion channel. My results are consistent with a trade elasticity in the range of 1 to 2, a value commonly used in the international business cycle literature and also found in Cravino (2014), who uses Chilean firm-level trade data. But my results differ from Ekholm et al. (2012), who find that an exchange rate appreciation leads to an increase in production.

The second part of this paper provides a quantitative assessment of the aggregate impact of an exchange rate devaluation. The empirical analysis that focuses on firms exposed to exchange rate changes is silent about the reaction of firms in the non-traded sector and ignores the general equilibrium effects of an aggregate devaluation. I therefore set up a small open economy model to analyze these effects in the context of a full model. The model incorporates Calvo-style nominal price and wage rigidity, both local and producer currency pricing as well as a downward sloping demand curve for Estonia's exports. A key parameter in my model is the degree of price stickiness, which I estimate from my firm-level data. I exploit the fact that some firms invoice their exports in a third country's currency and look at how changes in the invoicing currency affect the export price in Estonian kroons. I find that at an annual frequency, export prices in Estonian kroons increase by about 0.6 percent after a 1 percent depreciation of the invoicing currency, which corresponds to a quarterly value of 0.88 for the price stickiness parameter.

In my benchmark setting calibrated to the Estonian economy in 2009, a 10 percent devaluation of the Estonian kroon raises GDP by 5.2 percent upon impact. This strong effect is partially driven by an increase in exports, but also reflects an expansion of firms in the non-traded sector. This expansion occurs through two channels: First, a devaluation raises the cost of imports, causing firms to switch towards domestic substitutes. In the short-run when domestic prices are sticky, this intratemporal substitution effect outweighs the empirically observed import cost channel. Second, a devaluation stimulates domestic demand of consumers who expect higher prices in the future.

While the precise magnitude of the exchange rate effects are specific to the Estonian economy, some general lessons can be drawn: Devaluations are more expansionary in countries with more rigid prices and, more importantly, more rigid wages. A high trade elasticity and a low share of foreign currency invoicing reinforce the export expansion effect and therefore lead to stronger effects of a devaluation. Lastly, a country's trade openness is almost orthogonal to the benefits from a devaluation, mainly because both the non-traded sector and the export sector expand in equal amounts. A higher trade elasticity would change this result and make more open economies more sensitive to exchange rate fluctuations.

Some important considerations are in order when interpreting the results from my model: First, my model does not incorporate financial frictions that make devaluations contractionary through negative balance-sheet effects.[2] Available data on private firms' balance sheets in Estonia suggest that firms were highly leveraged during the crisis, but the public sector was almost debt-free so that appropriate debt transfers from the private to the public sector could have mitigated the negative balance sheet effects. Second, the strong expansionary effects rely on households and firms switching from imports to domestic products. Finding empirical support for these indirect effects is difficult and left for future research.[3]

This paper is related to several literatures. A large literature in international finance empirically studies the effect of exchange rate movements on pass-through and trade, mainly exports (see Burstein and Gopinath (2014a) for a good overview). Among papers using firm-level data,

[2]See e.g. Krugman (1999) and Céspedes et al. (2004). For empirical evidence of the balance-sheet effect, see Kim et al. (2015).

[3]Bems and Di Giovanni (2014) find evidence that Latvian consumers switched towards cheaper domestic goods during the financial crisis, but attribute this behavior to an income effect rather than a substitution effect.

Fitzgerald and Haller (2014) and Cravino (2014) estimate the response of export revenue to exchange rate movements using a dataset of Irish and Chilean firms, respectively. My estimates of the trade elasticity are similar to theirs. Similar to Cravino (2014), I find support that the invoicing currency is a main determinant of a firm's pass-through. Amiti et al. (2014) use Belgian data to point out the relevance of concurrent changes in import costs when studying the pass-through of exports. My model incorporates this channel, for which I also find support in the data.

Second, several studies have analyzed the effects of exchange rate movements on economic performance. Almost all of those studies are either based on country-level or industry-level data and generally find mixed results.[4] However, a major shortcoming of these studies is that even within narrowly defined industries, firms differ significantly in their trade patterns and exposure to currency fluctuations, which might explain the mixed findings. My paper is unique in that it combines these two strands of literature to analyze a firm's overall economic performance in response to exchange rate changes.

The rest of the paper is organized as follows. The next section introduces a simple firm decision problem to motivate the regressions and my empirical results in Section 3. Section 4 presents a small open economy model. Quantitative exercises of this model are performed and discussed in Section 5. The last section concludes.

2 Exchange Rate Movements and Firm Performance

In this section, I derive my estimation equation from a static firm-decision problem. I show that the firm's production decision depends on the price of its exports and the cost of its inputs, which includes the cost of imported inputs. If some of these prices and costs are preset in some invoicing currency, a firm's production decision depends on both the exchange rate of its trading partner and the exchange rate of its invoicing currency. Based on this insight, I define firm-specific

[4] See e.g. Campa and Goldberg (1995) and Gourinchas (1999) for an analysis of investment and employment in response to exchange rate movements in U.S. manufacturing industries, and Kim and Ying (2007) for a cross-country analysis.

effective exchange rates that take the invoicing currency into account. These exchange rates are the main covariates of interest in the subsequent empirical analysis.

Consider an Estonian firm producing a differentiated good i and supplying it to destination market n. The price for its product sold to destination n is $p^i_{n,\$}$ and is quoted in invoicing currency $\$$. The exchange rate of Estonian kroons vis-a-vis $\$$ is denoted $E_\$$ and its units are kroons over $\$$.[5] The only source of uncertainty for a firm is whether its price is flexible. With probability θ, firm i's price is preset and fixed at $\bar{p}^i_{n,\$}$. I abstract from a firm's invoicing choice and assume that the invoicing currency is preset. The firm operates a single production facility for exports to all its destinations, so that substitution across destinations is costless. Because the production function has constant returns to scale, the firm's marginal cost is independent of the amount produced. This nominal marginal cost is denoted MC^i and quoted in kroons.

Assume consumers in each market have a CES demand over varieties of goods. The elasticity of substitution across varieties is ψ. Then, market n's demand for firm i's production is

$$y^i_n = \omega^i_n \left(\frac{E_\$}{E_z} p^i_{n,\$}\right)^{-\psi} P^\psi_n Y_n \tag{I.1}$$

where $\omega^i_n \geq 0$ is a preference parameter, P_n is the aggregate price index in market n, and Y_n is total absorption of market n. The relevant price for the consumers is the dollar price converted into their local currency, $p^i_{n,z} = E_\$/E_z p^i_{n,\$}$, where the local currency in market n is denoted by subscript z. Log-differentiating the demand function (I.1) and aggregating over all markets n gives the change in total output $y^i = \sum_{n\in\mathbb{X}^i} y^i_n$ as a function of the firm's output price index, p^i, and a demand shifter, D^i, aggregated over all markets:

$$d\log y^i = -\psi d\log p^i + d\log D^i, \tag{I.2}$$

[5]The kroon is said to depreciate vis-a-vis $\$$ if $E_\$$ goes up.

with the change in firm i's output price index being $d\log p^i = \sum_{n\in\mathbb{X}^i} \frac{y_n^i}{y^i} d\log p_{n,z}^i$.[6] $\mathbb{X}^i$ is the set of destination markets for firm i (potentially including the home market). The expression for the change in the output price index, $d\log p^i$, depends on the firm's ability to adjust its price: If the firm has a preset price, then any changes in its price $p_{n,z}^i$ are driven by changes in the exchange rate between the invoicing currency and the destination's currency, $E_\$/E_z$. If the firm can adjust its price, then changes in the price $p_{n,z}^i$ are decomposed into changes of the adjusted price and changes in the exchange rates:

$$d\log p^i = \begin{cases} \left(\sum_{\$\in\mathbb{X}_\$^i} \frac{y_\$^i}{y^i} d\log E_\$\right) - \left(\sum_{n\in\mathbb{X}^i} \frac{y_n^i}{y^i} d\log E_z\right) & \text{if} \quad i\in\Theta \\ \sum_{n\in\mathbb{X}^i} \frac{y_n^i}{y^i} \left(d\log p_{n,k}^i - d\log E_z\right) & \text{if} \quad i\in\bar{\Theta}. \end{cases} \tag{I.3}$$

Here, $\mathbb{X}_\$^i$ is the set of invoicing currencies for firm i's exports, $y_\$^i$ is the value of its exports that are invoiced in currency \$, Θ denotes the set of firms with preset prices and $\bar{\Theta}$ its complement. The change in the adjusted price for the flexible-price firms is expressed in kroons, $p_{n,k}^i$.

In the next section, I will estimate ψ in equation (I.2). To that end, I need to measure the change in the output price index, $d\log p^i$. Most parts in (I.3) can be directly measured in the data, including changes in the exchange rates of the destination markets, E_z, and the invoicing currencies, $E_\$$, as well as trade shares by destination, $\frac{y_n^i}{y^i}$ and invoicing currency, $\frac{y_\$^i}{y^i}$. The remainder of this section shows that changes in the optimal price $p_{n,k}^i$ are linked to exchange rate changes in import markets. I also discuss how I estimate the probability that a firm cannot adjust its preset price, θ.

For a firm i with flexible prices, the maximization problem given a marginal cost MC^i is

$$\max_{p_{n,\$}^i} \left\{ \sum_{n\in\mathbb{X}^i} \left(E_\$ p_{n,\$}^i y_n^i\right) - MC^i y^i \right\}$$

[6] The demand shifter is defined as

$$d\log D^i = \sum_{n\in\mathbb{X}^i} \frac{y_n^i}{y^i} \left(d\log\omega_n^i + \psi d\log P_n + d\log Y_n\right).$$

subject to the demand function (I.1). The change in the optimal price equals the change in the marginal cost:

$$d \log p_{n,k}^{i} = d \log MC^{i}. \tag{I.4}$$

Since marginal costs are determined at the firm level in my model (as opposed to the firm-destination level), the kroon price is constant across destinations and the law of one price holds $d \log p_{n,k}^{i} = d \log p_{k}^{i}$.

To derive an expression for marginal cost, suppose that the firm requires labor l^i and intermediate goods q^i for production, with the share of wages in marginal costs being γ^i. The firm bundles intermediate goods from different sources using a CES aggregator. Let the wage be W and the kroon price of an intermediate good imported from country n be $v_{n,k}$. Then, the change in a firm's marginal cost can be decomposed into the change in its labor costs and the change in the price of intermediate goods:

$$d \log MC^{i} = \gamma^{i} d \log W + (1 - \gamma^{i}) d \log v^{i}, \tag{I.5}$$

where v^i is the price index of the intermediate goods bundle (in kroons), and its change is given by $d \log v^{i} = \sum_{n \in \mathbb{M}^{i}} \frac{q_{n}^{i}}{q^{i}} d \log v_{n,k}^{i}$. Here, $\mathbb{M}^i$ is the set of source markets for firm i (potentially including the home market). Analogous to firms in Estonia, suppose that firms in country n also face price rigidity. A fraction ϑ of firms exporting to Estonia has preset prices. Then, the change in the average import price in kroons for firm i is

$$d \log v_{n,k}^{i} = \vartheta d \log E_{\$} + (1 - \vartheta) \left(d \log E_{z} + d \log v_{n,z} \right). \tag{I.6}$$

Combining equations (I.4)-(I.6) gives[7]

$$d\log p_k^i = \gamma^i d\log W + (1-\gamma^i)\sum_{n\in\mathbb{M}^i}\frac{q_n^i}{q^i}\left[\vartheta d\log E_\$ + (1-\vartheta)\left(d\log E_z + d\log v_{n,z}\right)\right]. \tag{I.7}$$

Inserting this expression into (I.3) and taking the expected value gives[8][9]

$$\mathbb{E}\left(d\log p^i\right) = -d\log E_X^i + (1-\theta)(1-\gamma^i)d\log E_M^i + (1-\theta)\left(\gamma^i d\log W + (1-\gamma^i)d\log v_z^i\right), \tag{I.8}$$

where the effective firm exchange rates E_X^i and E_M^i are defined as follows:

Definition 1 (Expected effective firm exchange rate under sticky prices). *Let θ denote the probability that a firm's output invoiced in currency $\$ \in \mathbb{X}_\$^i$, $y_\$^i$, has a preset price. Then, the log change in the expected effective export exchange rate for a firm i selling y_n^i to markets $n \in \mathbb{X}^i$ with exchange rates E_z is given by*

$$d\log E_X^i = \left(\sum_{n\in\mathbb{X}^i}\frac{y_n^i}{y^i}d\log E_z\right) - \theta\left(\sum_{\$\in\mathbb{X}_\$^i}\frac{y_\$^i}{y^i}d\log E_\$\right). \tag{I.9}$$

Similarly, let ϑ denote the probability that a firm's imports invoiced in currency $\$ \in \mathbb{M}_\$^i$, $q_\$^i$, has a preset price. Then, the log change in the expected effective import exchange rate for a firm i importing q_n^i from market $n \in \mathbb{M}^i$ with exchange rates E_z is given by

$$d\log E_M^i = \vartheta\left(\sum_{\$\in\mathbb{M}_\$^i}\frac{q_\$^i}{q^i}d\log E_\$\right) + (1-\vartheta)\left(\sum_{n\in\mathbb{M}^i}\frac{q_n^i}{q^i}d\log E_z\right). \tag{I.10}$$

[7] A similar relationship between exchange rate movements and the optimal reset price can be derived in a dynamic setting, as I show in my general equilibrium framework. Under Calvo pricing, reset prices reflect expected changes in future marginal costs. If exchange rates follow a unit root process, firms reset prices one-to-one with changes in current exchange rates, so that my estimation equation remains unaffected.

[8] In my data, I do not classify firms into sticky-price and flexible-price firms. I therefore use this average (or expected) change in the output price index as my covariate. In the appendix, I show that the resulting estimator for ψ is still consistent (see appendix section Appendix A).

[9] The last term is the change in the price of firm i's imports, defined in the exporter's currency $d\log v_z^i = \sum_{n\in\mathbb{M}^i}\frac{q_n^i}{q^i}d\log v_{n,z}^i$.

These exchange rates are firm-level equivalents of the effective exchange rates at the aggregate level, but take into account the extent to which prices are sticky. As a result, the relevant exchange rates for calculating the index are a weighted average of the invoicing exchange rate and the trade partner's exchange rate, with the weight depending on the degree of price stickiness, θ and ϑ.

In the next section, I estimate θ as the elasticity of the export price in Estonian kroons with respect to the invoicing exchange rate. In my model, the average price in kroons across all firms is

$$p_{n,k} = \theta E_{\$} \bar{p}^{i}_{n,\$} + (1-\theta) p^{i}_{n,k}.$$

The elasticity of this average price with respect to the invoicing exchange rate is

$$\nu \equiv \frac{d \log p_{n,k}}{d \log E_{\$}} = \theta + (1-\theta) \frac{\partial p^{i}_{n,k}}{\partial E_{\$}}. \tag{I.11}$$

The elasticity corresponds to the fraction of firms with preset prices, θ, plus an additional term. This additional term reflects price adjustments of firms with flexible prices. When estimating (I.11) in the next section, I explain how I control for this second term to identify θ.

To summarize, I have shown that a firm's production decision (I.2) depends on exchange rates in its export market affecting the output price and exchange rates in the import market affecting the marginal cost. In the next section, I will estimate equation (I.2), where I use equation (I.8) to construct the change in a firm's output price index. In appendix section Appendix A, I derive similar expressions for changes in labor and the value of intermediate consumption. A depreciation of the export effective exchange rate E^{i}_{X} stimulates all three of them, whereas an appreciation of the import effective exchange rate E^{i}_{M} has an ambiguous effect on labor and the value of intermediate consumption, due to competing income and substitution effects.

3 Empirical Evidence on Exchange Rate Effects at the Firm Level

In this section, I estimate the firm production equation (I.2) introduced in the last section. I introduce my dataset of Estonian firms and present the distribution of the firm-specific exchange rates, my main covariate of interest. I then estimate the price stickiness parameter θ, which, together with the invoicing currency, controls the degree to which firms are exposed to exchange rate changes. Finally, I present and discuss my main empirical finding that both export and import exchange rates have a major impact on a firm's production decision, especially for larger firms.

3.1 Data

My analysis is based on two datasets provided by Statistics Estonia with annual data for 2003 - 2012. The first dataset has extensive trade data collected through the Extrastat and Intrastat system.[10] This trade data contains information on both imports and exports by product (CN 8-digit level) and firm, the partner country, the invoicing currency, the value in euros and the invoicing currency, and the net weight. I merge this dataset with data on firms' gross output, hours worked and intermediate consumption. This second dataset contains almost all private firms with 20 employed persons or more, in addition to a rotating sample of smaller firms, and is used by Statistics Estonia in their compilation of national accounts. I require firms to appear in at least two consecutive years, so that I can calculate growth rates, and firms must be involved in foreign trade. My resulting sample is therefore somewhat skewed towards larger firms and mainly includes firms in the manufacturing and the wholesale and retail trade sector. Overall, my sample includes almost 3,000 firms per year, which capture about 60 percent of Estonia's total trade in goods and 75 percent of value added in the private sector.

[10] Extrastat data are based on customs declarations for trade with non-EU countries, while Intrastat data for within-EU trade is based on statistical declarations and mainly misses small trade flows. The reporting thresholds for Intrastat in 2014 were annual imports of €130,000 and exports of €200,000.

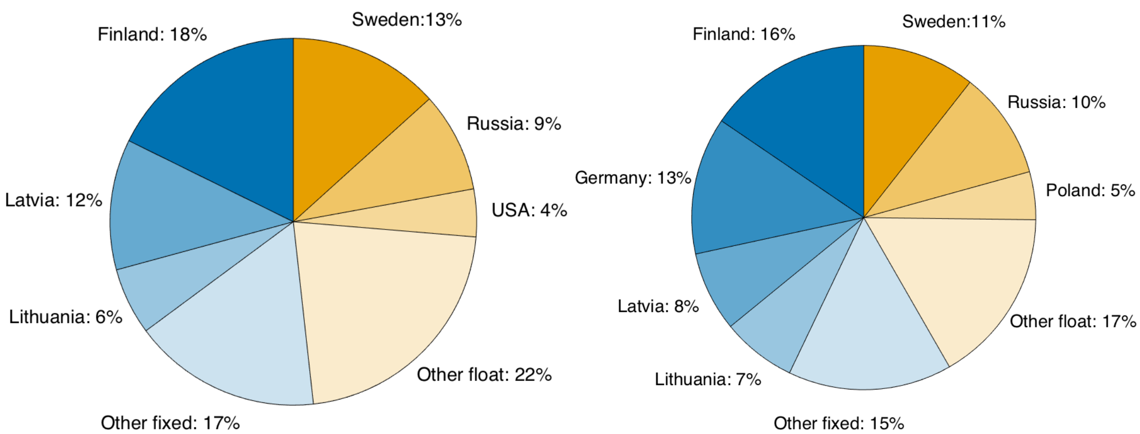
In analyzing the degree of price stickiness, my dependent variable is the log change in unit values, defined as the ratio of trade value to trade quantity (measured as weights). For my firm performance analysis, the dependent variables are the log change of nominal gross output, intermediate consumption and hours worked. My measures of gross output and intermediate consumption follow the concepts used in national accounts, e.g. gross output adds changes in inventories of finished goods to turnover. My estimation equation in (I.2) is written in real values. Using nominal values adds another control, which is the firm-specific effective exchange rate of the invoicing currency, but the estimated coefficient on $d \log p^i$ still corresponds to $-\psi$ (see appendix section Appendix A for details.)

I use my data to construct firm-specific changes in the export and import effective exchange rates, $d \log E_X^i$ and $d \log E_M^i$, as defined in equations (I.9) and (I.10). To calculate trade shares, I use the average trade share across $t-1$ and t. Details on the construction of these and the remaining variables (wages, foreign GDP, price level, and producer price index) as well as their data sources are provided in appendix section Appendix A.

3.2 Summary Statistics

Estonia is a useful environment for studying exchange rate movements because it is very open to trade and there is considerable heterogeneity across its trading partners. More than 50 percent of firms in my sample export and 75 percent import (see Table I.1). Among large firms with fifty employees or more almost nine out of ten firms import. Exporters sell about one third of their production abroad, whereas importers buy about 40 percent of their intermediate goods abroad. This represents roughly 30 percent of total variable costs (= labor costs + costs for intermediate goods). Even though this is a selected and small sample out of more than 50,000 firms operating in Estonia, it accounts for three quarters of total production and value added in the private sector. Hence, trade is not only important for this sample, but also for the economy as a whole.

Thanks to its peripheral position in the eurozone, Estonia trades with both eurozone countries and countries with floating exchange rates. This gives rise to variation in the exchange rate that



(a) Exports by Destination (b) Imports by Source

FIGURE I.1: ESTONIA'S TRADE PARTNERS, 2007

Note: Trade shares by value. 'Blue' colored countries are in the eurozone or considered to be pegged to the euro. 'Orange' colored countries have a floating exchange rate.

I exploit in my empirical analysis. Figure I.1 splits up Estonia's trade by trade partner. Roughly 50 percent of the total export value and 40 percent of the total import value is with floating exchange rate countries, mainly Sweden and Russia. As reported in Table I.2, there is somewhat less variation in the invoicing currency. Roughly 80 percent of all product-firm-year observations in my data sample is invoiced in euros (or Estonian kroons). This includes a substantial share of partner countries whose currency is not the euro. As a consequence of this large fraction, invoicing in the destination country's currency is substantially less common for exports than for imports: roughly 9 percent of exports outside the eurozone is priced in the buyer's currency, whereas 50 percent of imports from non-eurozone countries is priced in euros. There is also little difference between large and small firms. If anything, larger firms are less likely to invoice in the destination's currency and more likely to invoice in euros.

Estonian firms face some fluctuations in their effective exchange rates, as shown in Figure I.2. The figure displays the distribution of the annual change in the effective firm exchange rates, $\Delta E^i_{X,t}$ and $\Delta E^i_{M,t}$. In constructing the change in the exchange rates, I choose $\theta = 0.6$, which corresponds to the estimate obtained in the next section. Note that the exchange rate index also includes the domestic market for which the exchange rate change is zero. The two

Table I.1: Trade Exposure

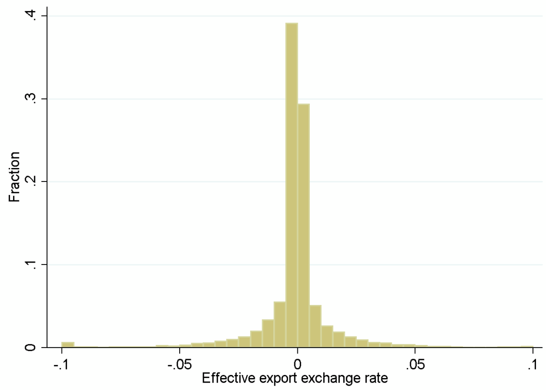
	All	Small	Large
# firms	2,872	2,038	834
% Exporters	56%	51%	70%
% Importers	76%	72%	85%
% Exporter & importer	46%	39%	63%
Average trade shares			
Exports (all)	23%	19%	31%
Exports (exporters only)	34%	31%	41%
Imports (all)	37%	36%	37%
Imports (importers only)	41%	42%	39%
Average material cost share	69%	71%	64%

Large firms refers to firms with 50 employees or more in the previous period. Sample of firms that either export or import. Numbers are averages across all years (2004 - 2012).

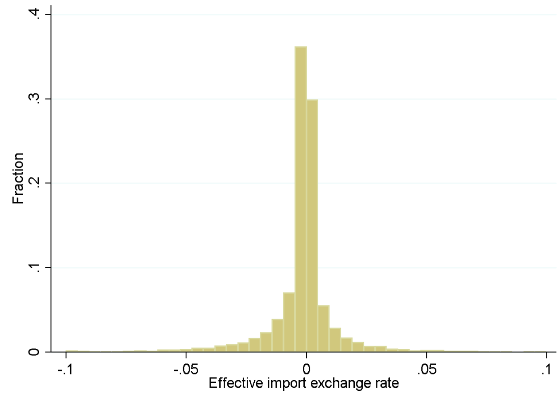
Table I.2: Invoicing Currency

	All firms		Large firms	
	Exports	Imports	Exports	Imports
Euros, partner country's currency euros	34%	51%	39%	54%
Euros; partner country's currency not euros	50%	25%	49%	27%
Partner country's currency (excluding euros)	6%	13%	5%	11%
Third country's currency	10%	10%	6%	8%

Notes: Large firms refers to firms with 50 employees or more in the previous period. Estonia's, Denmark's and Lithuania's currencies are treated as 'euros' because they had a fixed exchange rate over the sample period. Percentages refer to number of observations at the product-firm-year level across all years.



(a) Export exchange rate



(b) Import exchange rate

Figure I.2: Distribution of Effective Firm Exchange Rates

Note: Distribution of $\Delta E^i_{X,t}$ and $\Delta E^i_{M,t}$ across firms and years. Firms with zero change are excluded (40% for $\Delta E^i_{X,t}$, 20% for $\Delta E^i_{M,t}$). For this figure, exchange rate changes are capped at -0.1 and 0.1.

figures display some variation in the exchange rate that firms face, both in the export and import market, with a standard deviation of 1.2 percent. The average correlation between export and import exchange rates within firms across years is 32 percent, indicating that firms have some tendancy to export to and import from the same partner country and / or in the same invoicing currency. The typical firm is therefore somewhat hedged against exchange rate movements. Recalculating the effective exchange rates based on invoicing currencies alone, i.e. $\theta = 1$, gives a lower correlation of only 20 percent. This suggests that firms do not actively choose their invoicing currency to hedge against exchange rate risks.

In summary, Estonian firms differ in their trade and exchange rate exposure, and to a lesser degree, in their invoicing currency exposure. In the next section, I exploit this variation to analyze how fluctuations in exchange rates affect a firm's production decision.

3.3 Empirical Findings

Price Rigidity

I start by presenting evidence that prices are somewhat sticky in the invoicing currency. For that, I estimate equation (I.11). A challenge is that the elasticity of the export price in Estonian kroons with respect to the invoicing exchange rate, ν, captures both nominal rigidities (θ) and changes in the desired price $\left(\frac{\partial p^i_{n,k}}{\partial E_\$}\right)$. This makes it difficult to disentangle the two from each other. For instance, consider Estonian exports to Russia invoiced in rubles. If, following an appreciation of the ruble, the export price in Estonian kroons increases one by one, then this could be because Estonian exporters *cannot* adjust their ruble price to keep their kroon price constant, or it could be because Estonian exporters *do not wish* to adjust their ruble export price. This later response is consistent with models that allow for variable markups: An appreciation of the ruble lowers the price of Estonian exporters relative to the price level in Russia. Facing less competition, Estonian exporters might increase their markup and prevent their ruble export price from falling too much.[11] In that case, I would misinterpret a high elasticity estimate as a sign of price stickiness, whereas it really indicates that firms do not wish to adjust their prices.

My data allows me to disentangle the two effects by controling for several factors that affect a firm's desired export price in kroons. In particular, my identification of θ comes from Estonian firms that invoice in a third country's currency, for instance exporters to Russia invoicing in U.S. dollars. I control for the exchange rate, the price level and GDP of the destination's country because these factors might all be correlated with the invoicing currency exchange rate and the desired export price. Importantly, I also include firm-year fixed effects to control for changes in marginal costs at the firm level that might be correlated with changes in the invoicing exchange rate (e.g. changes in the price of imports). My estimation regression is therefore

$$\Delta \log p^{i,p}_{n,\$,t}(k) = \beta_1 \Delta \log E_{\$,t} + \beta_2 \Delta \log E_{z,t} + \beta_3 \Delta \log D'_{n,t} + d_n + d^i_t + \varepsilon^{i,p}_{p,n,\$,t}(k). \tag{I.12}$$

[11] See Burstein and Gopinath (2014a) and Berman et al. (2012) for a discussion of those models.

The dependent variable, $\Delta \log p^{i,p}_{n,\$,t}(k)$, is the log change of the unit value price charged on exports of product p (defined at the 8 digit CN) to country n at time t, invoiced in $\$$ and quoted in Estonian kroons.[12] $\Delta \log E_{\$,t}$, is the exchange rate between the invoicing currency and the kroon (units of kroons per units of invoicing currency) at time t.

The first column in Table I.3 displays the results. The coefficient on $\Delta \log E_{\$,t}$ is positive and highly significant. A 1 percent appreciation of the invoicing currency leads to a 0.6 percent increase in the kroon price. This estimate indicates a moderate degree of price stickiness, which is in line with parameter values used in closed economy New Keynesian DSGE models: at quarterly frequency, my estimate implies a Calvo parameter of 0.88 ($= 0.6^{1/4}$), which is the estimate used in Del Negro et al. (2013).[13]

I assume that the degree of price rigidity is the same for both Estonian firms and foreign firms exporting to Estonia, that is I set $\theta = \vartheta = 0.6$ to construct the effective exchange rates, $\Delta \log E^i_X$ and $\Delta \log E^i_M$.

Effects on Firm performance

To estimate the effect of exchange rate movements on a firm's production, I run the following regression:

$$\Delta \log x_t = \sum_{j=0}^{T} \beta_{1,j} \Delta \log E_{X,t-j} + \sum_{j=0}^{T} \beta_{2,j}(1-\gamma)\Delta \log E_{M,t-j} + \sum_{j=0}^{T} \boldsymbol{\beta_{3,j}} \Delta \log \mathbf{Z'_{t-j}} + d + \varepsilon_t \tag{I.13}$$

[12] The model presented in the previous section was written for a single-product firm producing a differentiated good i. This was done for simplicity. As long as production decisions across products within firms do not affect each other, the results also hold for multi-product firms. In this section, I make this explicit by introducing a superscript p to indicate a product.

[13] My estimate is lower than the one found in Cravino (2014), who reports that producer prices move one-to-one with the exchange rate of the invoicing currency for a set of Chilean firms. One possible reason for my lower estimate is that I control for firm-level changes in marginal costs, e.g. caused by concurrent increases in import prices in response to exchange rate changes. As shown later in this section and by Amiti et al. (2014), these concurrent movements in import prices affect a firm's desired price.

Table I.3: Nominal Rigidities and Pass-Through

	Export price ($\Delta \log p^i_{n,t}$)					Import price ($\Delta \log(v^i_{n,t})$)			
	Kroons	Destination currency				Kroons			
	All (1)	All (2)	All (3)	Small (4)	Large (5)	All (6)	All (7)	Small (8)	Large (9)
$\Delta \log E_{z,t}$	0.018	−0.893***	−0.934***	−0.880***	−0.984***	0.309**	0.186***	0.201***	0.156***
	(0.027)	(0.021)	(0.021)	(0.031)	(0.030)	(0.040)	(0.040)	(0.022)	(0.030)
$\Delta \log E_{\$,t}$	0.594***		0.572***	0.673***	0.366***		0.445***	0.428***	0.479***
	(0.050)		(0.039)	(0.051)	(0.063)		(0.047)	(0.031)	(0.043)
$\Delta \log D_{y,n,t}$	−0.045	0.003	0.011	0.048	−0.028				
	(0.042)	(0.031)	(0.032)	(0.045)	(0.045)				
$\Delta \log D_{p,n,t}$	0.091***	0.160***	0.142***	0.210***	0.069*				
	(0.031)	(0.024)	(0.024)	(0.034)	(0.035)				
$\gamma^i \Delta \log W_t$			−0.186***	−0.245***	−0.084				
			(0.051)	(0.066)	(0.086)				
$(1-\gamma^i)\Delta \log E^i_{M,t}$			0.364***	0.469***	0.190				
			(0.095)	(0.124)	(0.156)				
$(1-\gamma^i)\Delta \log v^i_{z,t}$			0.209***	0.271***	0.079				
			(0.0546)	(0.069)	(0.097)				
$\Delta \log v_{n,t}$						0.027	0.015	0.024*	−0.006
						(0.029)	(0.022)	(0.014)	(0.019)
Fixed effects:									
$\delta_n + \delta^i_t$	Yes	No	No	No	No	No	No	No	No
$\delta_{s,n} + \delta_t$	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	219,434	219,434	219,434	114,365	105,069	694,367	694,367	407,020	287,347
R^2	0.142	0.033	0.034	0.035	0.044	0.011	0.011	0.01	0.018

Notes: Observations are at the firm-country-product-invoicing currency-year level. Large firms refer to firms with lagged employment of 50 persons or more. Standard errors clustered at the firm level. Standard errors clustered at country-year level. Fixed effects:$\delta_n + \delta^i_t$ is the combination of partner country and firm-year fixed effects; $\delta_{s,n} + \delta_t$ is the combination of partner-sector and year fixed effects (the sector is defined at the NACE-2 level). Observations are excluded if the log difference in the unit value is less than -0.67 or more than 2, or if the change in the export or import quantity is in the top and bottom one percentile Years 2004 - 2012.

where x_t^i is either gross output, intermediate consumption or hours worked, and $T = 0, 1, 2$ is the number of lags. My main covariates of interest are the log changes in the effective firm exchange rates for exports and imports, $\Delta \log E_{X,t}^i$ and $\Delta \log E_{M,t}^i$. I premultiply the import exchange rate by the share of material costs in total costs because my model predicts that a firm's response to changes in the import exchange rate should depend on the share of imports in total costs. I also add several controls suggested by model, $\Delta \log Z_t^{i'}$, to pick up changes in demand in the foreign market, changes in marginal costs at the firm level and, for changes in gross output, changes in the invoicing currency exchange rate.

The short-run contemporaneous elasticity of the output variable x_t^i with respect to the export and import exchange rates are $\beta_{1,0}$ and $\beta_{2,0}$. Medium-run elasticities are calculated as the sum of the coefficients, $\beta_1(T) = \sum_{j=0}^{T} \beta_{1,j}$ and $\beta_2(T) = \sum_{j=0}^{T} \beta_{2,j}$, and reflect the impact of current exchange rates on outcome variable over time. I start by discussing the contemporaneous elasticities.

As reported in Table I.4, both export and import exchange rates affect the firm in the expected direction. Columns (1), (4) and (7) display the baseline results for all the firms in my sample. A 1 percent depreciation of the effective export exchange rate raises gross output by 1.25 percent, intermediate consumption by 1.1 percent and hours worked by almost 0.5 percent. All coefficients are highly statistically significant. The import exchange rate has a somewhat weaker effect: A 1 percent appreciation, adjusted for the material cost share, raises gross output by 0.5 percent, but this effect is statistically not significant. It raises intermediate consumption and hours worked by 0.75 and 0.65 percent, with both coefficients being statistically significant at the 10 and 5 percent level, respectively.

These findings suggest a value for the demand elasticity of around 1.25. The somewhat weaker effects of changes in the import exchange rates on gross output is in line with the predictions of the model. Marginal cost shocks only affect output through their effect on the output price. In a model with sticky prices, this effect is mitigated. The response of labor and the value of intermediate consumption to changes in the import exchange rate are guided by two compet-

Table I.4: Effect of Exchange Rates on Firm Performance

	Gross output $\Delta \log(p_t^i(k) y_t^i)$			Intermediate consumption $\Delta \log(v_t^i q_t^i)$			Hours worked $\Delta \log l_t^i$		
	All (1)	Small (2)	Large (3)	All (4)	Small (5)	Large (6)	All (7)	Small (8)	Large (9)
$\Delta \log E^i_{X,t}$	1.247^{***}	1.029^{*}	1.992^{***}	1.173^{***}	1.120^{**}	1.403^{***}	0.457^{**}	0.375	0.638^{***}
	(0.428)	(0.563)	(0.514)	(0.403)	(0.531)	(0.462)	(0.213)	(0.300)	(0.234)
$(1-\gamma^i)\Delta \log E^i_{M,t}$	-0.480	-0.184	-1.491^{*}	-0.755^{*}	-0.712	-0.995	-0.632^{**}	-0.377	-1.516^{***}
	(0.490)	(0.639)	(0.791)	(0.448)	(0.550)	(0.818)	(0.298)	(0.374)	(0.467)
$\gamma^i \Delta \log W_t$	0.236	0.289	0.188	-0.094	-0.184	0.022	0.013	-0.009	0.021
	(0.254)	(0.316)	(0.307)	(0.241)	(0.289)	(0.354)	(0.147)	(0.180)	(0.181)
$(1-\gamma^i)\Delta \log v^i_{z,t}$	0.479^{*}	0.486	0.192	0.011	-0.072	0.179	-0.275	-0.167	-0.582^{**}
	(0.284)	(0.334)	(0.428)	(0.285)	(0.319)	(0.470)	(0.214)	(0.262)	(0.275)
$\Delta \log D_{y,n,t}$	0.758^{**}	0.960^{***}	0.412	-0.132	-0.026	-0.304	-0.377^{**}	-0.338	-0.381^{**}
	(0.294)	(0.370)	(0.339)	(0.304)	(0.349)	(0.358)	(0.174)	(0.231)	(0.181)
$\Delta \log D_{p,n,t}$	0.347		0.459	0.361	0.169	0.521	0.434^{**}	0.382	0.555^{*}
	(0.389)	(0.495)	(0.496)	(0.366)	(0.439)	(0.471)	(0.216)	(0.266)	(0.286)
$\Delta \log E^i_{\$,t}$	1.235^{**}	2.137^{**}	1.195^{**}						
	(0.536)	(0.853)	(0.531)						
Fixed effects:									
$\delta_t + \delta^i$	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	25,845	18,337	7,508	25,820	18,337	7,483	25,502	17,994	7,508
R^2	0.429	0.473	0.421	0.372	0.362	0.374	0.431	0.516	0.434
1% devaluation:									
Net effect	0.09	0.10	0.09	-0.03	-0.03	0.17	-0.11	-0.05	-0.18
Export effect	0.21	0.15	0.42	0.20	0.17	0.30	0.08	0.06	0.13
Import effect	-0.12	-0.05	-0.33	-0.19	-0.20	-0.22	-0.16	-0.11	-0.34

Notes: Observations are at the firm-year level. Dependent variables are: (1)-(3) log change in gross output, (4)-(6) log change in intermediate consumption, and (7)-(9) log change in hours worked. Large firms refer to firms with lagged employment of 50 persons or more. Standard errors clustered at the firm level. Fixed effects are a combination of firm and year fixed effects. Years 2004 - 2012. The effect of a 1 percent devaluation is calculated for a firm that both exports and imports with average trade shares and material cost shares as in Table I.1. The assumed share of foreign currency invoicing is 83% for exports and 84% for imports. The net effect is the sum of the effect of changes in the export exchange rate E_X and the effect of changes in the import exchange rate E_M.

ing effects: On the one hand, firms raise their output price in response to an increase in import prices. This lowers demand for their output and hence, firms also demand fewer inputs. On the other hand, firms substitute towards labor and the *value* of intermediates also rises. The negative coefficient suggests that the first effect dominates the second effect. In addition, the similar coefficient for labor and the value of intermediates is consistent with a unit elasticity of substitution between the two inputs.

The table also reveals that larger firms (50 employees or more) are more sensitive to exchange rate movements than smaller firms. I first estimate a separate price rigidity parameter for both groups of firms by re-running regressions similar to (I.12).[14] The estimated values in columns (4) and (5) of Table I.3 are $\theta = 0.67$ for small firms and $\theta = 0.37$ for large firms, which suggests that larger firms have less rigid prices. The elasticities of the value of output, intermediate consumption and hours worked with respect to the export exchange rate are 2, 1.4 and 0.65. This can be interpreted as larger firms facing a higher demand elasticity. Larger firms also react more strongly to changes in the import exchange rate. This is in line with the finding that they have less rigid prices, so that marginal cost changes more directly translate into output price changes.[15]

Figure I.3 displays the output elasticities as a function of the time lag. A 1 percent depreciation of the export exchange rate leads to a 1.25 percent increase in gross output within the year of the depreciation. After one year, this increase raises to almost 2 percent before it returns to 1.5 percent. A similar response can be observed for intermediate consumption and hours worked. Changes in the import exchange rates also have stronger effects after one year. A one percent depreciation of the import exchange rate lowers output by a cumulative 1.7 percent after one

[14] I run the regression without firm-year fixed effects, but control for changes in marginal costs at the firm level. For that, I assume that both types of firms face the same degree of price rigidity in their import markets, $\vartheta = 0.6$. Based on this estimate I can construct the change in the import exchange rate, $\Delta \log E_M^i$.

[15] The finding that the performance of larger firms is more sensitive to exchange rate movements is somewhat at odds with findings in the literature on the pass-through of larger firms. For instance, Berman et al. (2012) finds that larger firms tend to absorb exchange rate movements in their markups so that their export volumes are less sensitive. My finding, however, is consistent with models where price adjustments require a fixed cost so that larger firms change prices more often, and models where larger firms self-select into markets with higher demand elasticities because fixed export costs increase less than proportionally with firm size.

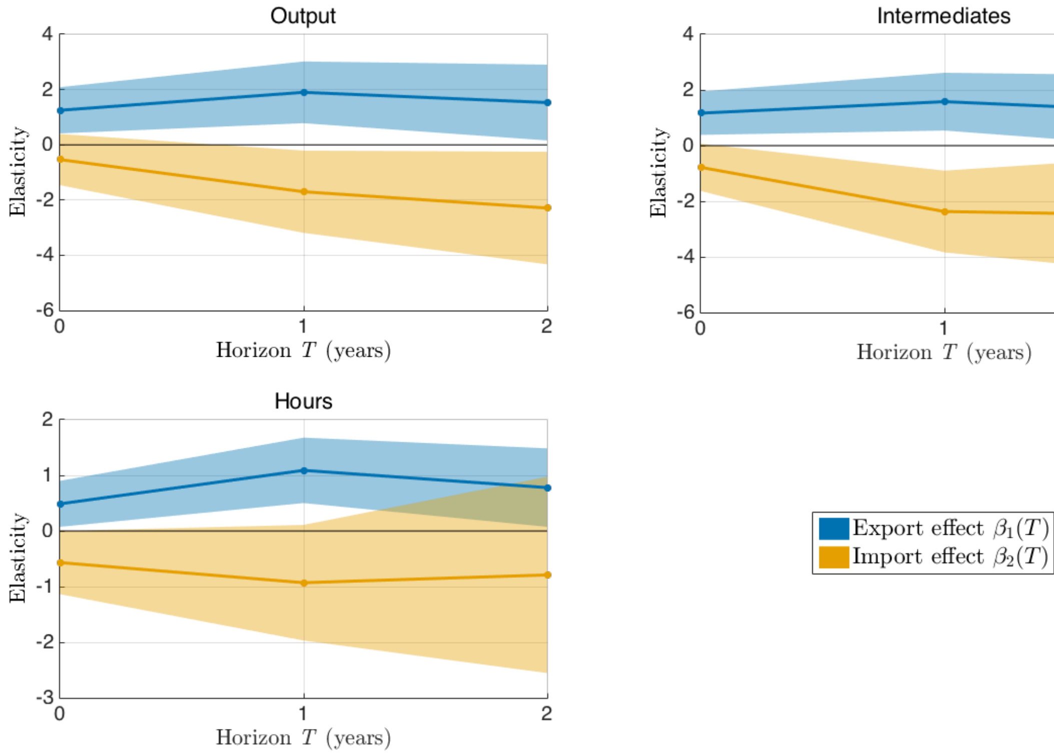


FIGURE I.3: ELASTICITY TO EXCHANGE RATES AT DIFFERENT HORIZONS
Notes: Figure displays the the elasticity of gross output, intermediate consumption and hours worked to the current effective export and import exchange rate at different horizons. The elasticities are calculated as the sum of the coefficients $\beta_1(T) = \sum_{j=0}^{T} \beta_{1,j}$ and $\beta_2(T) = \sum_{j=0}^{T} \beta_{2,j}$ for each lag specification. The bands represent the 95 percent confidence interval around the point estimate for each lag specification.

year and even 2.3 percent after two years. This is consistent with firms slowly increasing their prices over time in response to increases in the cost of imports. Overall, exchange rate movements have a persistent effect on output, which actually becomes somewhat stronger after one to two years.

The last part of Table I.4 displays the implied effect of a currency devaluation of the Estonian kroon. The first row looks at the net effect, which is then broken up into the effects due to changes in the export exchange rate and effects due to changes in the import exchange rate. The assumed trade and material cost shares are averages for a firm that both exports and imports (see Table I.1). The share of foreign currency invoicing is taken to be 83 percent for exports and 85 percent for imports, which are the value shares observed in Estonian trade data in 2009. The net effect of a 1 percent devaluation is 0.09 percent for (real) gross output, -0.03 percent for intermediate consumption and -0.11 for hours worked.[16] For larger firms, the net effect on output is also 0.09 percent, but more negative for hours worked: -0.18 percent. Overall, a depreciation is therefore slightly expansionary, but leads to a reduction in hours worked. In other words, a depreciation increases labor productivity. This is in contrast to the finding in Ekholm et al. (2012). They find that the currency *appreciation* in Norway in 2001-2002 led to a fall in employment among net exporting firms, but an increase in production.[17] The modest expansionary net effect of a devaluation can be explained by the small export effect displayed in the following row. The export effect is small despite the large estimated coefficients because the share of foreign invoicing for exports is high. Later, in the quantitative analysis of my general equilibrium model, I compare these partial equilibrium predictions to my model's responses.

In the last part of this section, I provide evidence for two underlying assumptions of my model: Both invoicing currency exchange rates and import exchange rates affect a firm's output prices. The underlying assumption for these results is that invoicing currency composition is a main factor in explaining incomplete exchange rate pass-through. Results in Table I.3 support this claim. Columns (2)-(9) display the results of standard pass-through regressions of the form described in (I.12). The dependent variable is either the log change in the export price quoted in the destination's currency or the log change in the import price quoted in Estonian kroons. Ignoring the invoicing currency, the pass-through is 0.89 for exports and 0.31 for imports.[18] However, a large share of exports is invoiced in the producer's currency, while most imports are in-

[16]As an example, the effect for all firms on gross output, 0.09, is calculated as

$$\begin{aligned} 0.09 &= s_X \hat{\beta}_1^{go} \left(1 - \hat{\theta} s_{X,\$}\right) - s_M (1-\gamma) \hat{\beta}_2^{go} \left(1 - \hat{\theta}(1 - s_{M,\$})\right) \\ &= 0.34 * 1.247 * (1 - 0.594 * 0.83) - 0.41 * 0.69 * 0.48 * (1 - 0.594 * (1 - 0.85)), \end{aligned}$$

where s_X^i is the export share, s_M^i is the import share, $s_\$^i$ is the share of trade invoiced in foreign currency.

[17]A possible reason for this contrasting finding could be differences in identification. Identification in Ekholm et al. (2012) comes from heterogeneity in a firm's net export position during a stark appreciation of the Norwegian currency in 2001-2002. They attribute the exchange rate appreciation to changes in Norwegian monetary policy, which might affect employment and production through other channels than the exchange rate, potentially explaining our partially divergent results. Identification in my paper does not only come from firm variation in net exports, but I also exploit variations in exchange rate movements across firms with similar export or import exposure, but trading with different countries and invoicing in different currencies.

[18]Berman et al. (2012) report a similarly high pass-through of 0.92 for French exporters, whereas Gopinath and Rigobon (2008) find a low pass-through of 0.22 for U.S. imports.

voiced in the consumer's currency. Controling for this asymmetric currency composition, the pass-through for exports and imports invoiced in the producer's currency are 0.93 and 0.63 respectively (see columns (3) and (7)). Accounting for the invoicing currency composition therefore makes the pass-through more complete.[19]

Besides the relevance of the invoicing currency, my model has also pointed out that changes in the import exchange rate affect a firm's production decision because it affects a firm's output price. This mechanism finds support in the data. Results in column (3) show that roughly one third of changes in the import exchange rate are passed on to output prices.[20]

To summarize, these numbers provide evidence for both the export expansion channel and the import cost channel of an exchange rate depreciation, with a stronger effect of the export expansion channel. The elasticity of output with respect to the export exchange rate is between 1.25 and 2, whereas it is between -0.5 and -1.5 with respect to the import exchange rate. My results also suggest that prices are somewhat sticky ($\theta = 0.59$) and that the net effect of a devaluation of the Estonian kroon on firm output therefore depends on the invoicing currency. In particular, since most Estonian trade is invoiced in foreign currency, the export expansion effect of such a devaluation would be small, so that the estimated net effect would be modest. However, these firm-level results do not inform about the reactions of firms in the non-traded sector. To quantitatively assess their reaction and compare the aggregate response to my firm-level estimates, the next section sets up a general equilibrium model that is calibrated to the firm-level findings of this section.

[19]Gopinath (2015) also finds cross-country evidence that the invoicing currency is a main determinant for the pass-through.

[20]This also affects the pass-through and can help explain why the import pass-through is lower than the export pass-through even after controling for the invoicing currency composition. To the extent that Estonia's import partners have a strong correlation between their export and import exchange rates (which is likely if most of their trade is with the euro area), the estimated import pass-through for Estonia will be low. For example, Swedish firms exporting to Estonia will not adjust their euro export price after a euro depreciation if a substantial share of their inputs is imported from the euro area. The relevance of this import cost channel and more empirical support can be found in Amiti et al. (2014).

4 A Semi-Small Open Economy Model with Nominal Rigidities

The model in this section is a semi-small open economy version of the New Keynesian multi-country model studied in House et al. (2015). Following Kehoe and Ruhl (2009), I model Estonia as a small open economy in the sense that it takes world interest rates as given, but Estonia is not small in the goods market, where it faces a downward sloping demand curve. As in House et al. (2015), my model features nominal price and wage rigidity to analyze the effects of changes in the nominal exchange rate on the real economy. I incorporate two additional features: First, the economy features a domestic and an export sector to study the interaction of changes in the exchange rate on firms in the traded and non-traded sector. Domestic goods are combined with imports to produce consumption goods. Second, a share of prices in the export and import sectors are invoiced in foreign currency, as observed in the data. The size of this share will affect the transmission of exchange rate movements through the economy. Ultimately, I will use the model to quantify the aggregate impact of exchange rate changes on the real economy and compare my results to my firm-level estimates.

4.1 Households

The model is written in per capita terms. In each period t the economy experiences one event s_t from a potentially infinite set of states. I denote by s^t the history of events up to and including date t. The probability at date 0 of any particular history s^t is given by $\pi(s^t)$.[21] The semi-small open economy has a representative household whose expected discounted sum of future period utilities is

$$\sum_{t=0}^{\infty}\sum_{s^t}\pi(s^t)\beta^t\left[\frac{C_t^{1-\frac{1}{\sigma}}}{1-\frac{1}{\sigma}}-\kappa\frac{L_t^{1+\frac{1}{\eta}}}{1+\frac{1}{\eta}}\right],$$

[21] Unless confusion arises, I write X_t instead of $X(s^t)$.

where $\beta < 1$ is the subjective time discount factor, σ is the intertemporal elasticity of substitution for consumption, η is the Frisch labor supply elasticity and κ is a weight on the disutility of labor in sector j. C_t is consumption of the final good and L_t is labor. The household chooses consumption of the final good $C_t \geq 0$, as well as next period's capital stock $K^j_{t+1} \geq 0$ and current investment into capital X^j_t for both sectors j, for all s^t, $t \geq 0$, to maximize the expected discounted sum of future period utilities subject to a sequence of budget constraints. In addition, the household determines the utilization level of the capital stock, u^j_t. Increasing utilization entails a nominal cost $P_t a(u^j_t)$.[22] The allocation of labor L_t is decided by monopolistically competitive labor supply unions (see section 4.1).

Households spend part of their income on consumption and investment goods, which they purchase at price P_t.

The households own the sector-specific capital stocks K^j_t of the economy. I introduce investment adjustment costs to make re-allocation of capital across sectors costly. The households supply labor and capital to the goods producing firms. In return, they earn nominal wages $W_t L_t$ and nominal payments for capital, adjusted for utilization, $\sum_j u^j_t R^j_t K^j_t$. Here W_t is the economy-wide nominal wage and R^j_t is the nominal rental rate of capital that prevails in sector j at time t. The household also receives profits from domestic firms. Let Π^j_t be nominal profits in sector j paid to the household at time t.

In addition to direct factor incomes, the household earns interest on non-contingent bonds. The household has access to two one-period bonds. The first bond is a purely domestic bond, denominated in the domestic currency, Estonian kroons. Let B_t be the quantity of those bonds purchased by the household in t. Their nominal interest rate is i_t. The second bond is an international bond, denominated in euros and denoted by $B^{€}_t$. The gross nominal interest rate on those international bonds is $1 + i^{€}_t + \iota(B^{€}_t)$, where $i^{€}_t$ is the euro interest rate at time t and $\iota(B^{€}_t)$ is a debt-elastic risk premium with $\iota'(B^{€}_t) < 0$.[23] The nominal exchange rate of Estonian kroons

[22] Following Christiano et al. (2014), I assume that the utilization cost function is $a(u) = \frac{R^j}{P}[exp\{h(u-1)\}-1]\frac{1}{h}$, where the curvature parameter h governs how costly it is to increase or decrease utilization from its steady-state value of $u = 1$. Note that in steady state, $a(u) = 0$.

[23] As is well known, small open economy models with incomplete asset markets feature a steady state that de-

vis-a-vis euros is denoted E and its units are kroons over euros.

The nominal budget constraints for the representative household are

$$P_t\left(C_t+\sum_{j=d,x}X_t^j\right)+E_tB_t^{€}+B_t=W_tL_t+\sum_{j=d,x}\left[\left(u_t^jR_t^j-a(u_t^j)P_t\right)K_t^j+\Pi_t^j\right]$$
$$+E_t\left(1+i_{t-1}^{€}+\iota(B_{t-1}^{€})\right)B_{t-1}^{€}+(1+i_{t-1})B_{t-1}.$$

And the law of motion for capital is

$$K_{t+1}^j=K_t^j\left(1-\delta\right)+\left[1-f\left(\frac{X_t^j}{X_{t-1}^j}\right)\right]X_t^j \qquad \forall j$$

with $f(1)=f'(1)=0$ and $f''(1)\geq 0$. As in Christiano et al. (2005), the function $f\left(\cdot\right)$ features higher-order adjustment cost on investment if $f''\left(1\right)>0$.

The first-order conditions for an optimum are as follows. The household's Euler equations for purchases of domestic and intenational bonds, B_t and $B_t^{€}$, require

$$E_t\frac{U_{1,t}}{P_t}=\beta\left(1+i_t^{€}+\iota_t\right)\sum_{s^{t+1}}\pi(s^{t+1}|s^t)E_{t+1}\frac{U_{1,t+1}}{P_{t+1}} \tag{I.14}$$
$$\frac{U_{1,t}}{P_t}=\beta\left(1+i_t\right)\sum_{s^{t+1}}\pi(s^{t+1}|s^t)\frac{U_{1,t+1}}{P_{t+1}}, \tag{I.15}$$

where $\iota_t=\iota(B_t^{€})$ and $U_{1,t}$ denotes the marginal utility of consumption at time t. The optimal choice for capital and investment in capital requires

$$\nu_t^j=\beta\sum_{s^{t+1}}\pi(s^{t+1}|s^t)\left(U_{1,t+1}\left(u_{t+1}^j\frac{R_{t+1}^j}{P_{t+1}}-a(u_{t+1}^j)\right)+(1-\delta)\nu_{t+1}^j\right)$$
$$U_{1,t}=\nu_t^j\left[1-f_t^j-f_t^{j'}\frac{X_t^j}{X_{t-1}^j}\right]+\beta\sum_{s^{t+1}}\pi(s^{t+1}|s^t)f_{t+1}^{j'}\nu_{t+1}^j\left(\frac{X_{t+1}^j}{X_t^j}\right)^2$$

where the notation f_t^j denotes the value of f evaluated at X_t^j/X_{t-1}^j. The nominal price of installed capital good j is $\mu_t=\nu_t^j/U_{1,t}P_t$.

pends on initial conditions (see Schmitt-Grohé and Uribe, 2003)). I follow the literature and introduce a debt-elastic risk premium to induce stationarity. I assume the functional form $\iota(B^{€})=\bar{\iota}\left(e^{\bar{B}^{€}-B^{€}}-1\right)$, where $\bar{B}^{€}$ denotes the steady-state bond level.

Households choose a sector-specific capital utilization level that satisfies

$$R_t^j = P_t a'(u_t^j).$$

Wage Setting

I follow the treatment by Erceg et al. (2000) and Christiano et al. (2005). The household supplies labor to firms through unions that have some market power. Specifically, I assume that *effective* labor is a CES mix of different labor types. These labor types are aggregated by aggregation firms that then supply the labor aggregate to the firms (in either sector) at a nominal wage of W_t. Effective labor is given by

$$L_t = \left(\int_0^1 l_t\left(z\right)^{\frac{\psi_l - 1}{\psi_l}} dz \right)^{\frac{\psi_l}{\psi_l - 1}}$$

where $l_t\left(z\right)$ is the amount of type s labor supplied. The parameter $\psi_l > 1$ governs the degree to which different labor types are substitutable. The labor aggregating firm behaves competitively and supplies effective labor to the firms at the nominal wage W_t, but hires labor by type according to the type-specific nominal wages $w_t\left(z\right)$. Demand for each labor type is

$$l_t\left(z\right) = L_t \left(\frac{w_t\left(z\right)}{W_t} \right)^{-\psi_l} \tag{I.16}$$

and the competitive aggregate nominal wage at time t is

$$W_t = \left(\int_0^1 w_t\left(z\right)^{1-\psi_l} dz \right)^{\frac{1}{1-\psi_l}}.$$

Wages for each type of labor are set by monopolistically competitive worker-types. Given the elasticity of demand $-\psi_l$, workers desire a real wage $w_t\left(z\right)/P_t$ which is a constant markup over the marginal rate of substitution between consumption and leisure, $-U_{2,t}/U_{1,t}$ (i.e., the competitive wage). The desired markup is $\mu_w = \frac{\psi_l}{\psi_l - 1} > 1$.

As in Erceg et al. (2000), I model sticky wages with a Calvo mechanism. Let θ_w be the probability that a worker cannot reset his wage in a given period. Whenever possible, workers reset wages to maximize the utility of the representative household. The marginal benefit of additional money at time $t+r$ is $U_{1,t+r}/P_{t+r}$ and the marginal disutility to the representative household from supplying additional labor is $-U_{2,t+r}$. Workers take the demand curve (II.5) as given whenever they can choose a new reset wage. Denote the optimal reset wage at time t by $\hat{w}_t$. The optimal reset wage satisfies

$$\hat{w}_t = \frac{\psi_l}{\psi_l - 1} \frac{\sum_{r=0}^{\infty} (\theta_w \beta)^r \sum_{s^{t+r}} \pi(s^{t+r}|s^t) L_{t+r} (W_{t+r})^{\psi_l} U_{2,t+r}}{\sum_{r=0}^{\infty} (\theta_w \beta)^r \sum_{s^{t+r}} \pi(s^{t+r}|s^t) L_{t+r} (W_{t+r})^{\psi_l} \frac{U_{1,t+r}}{P_{t+r}}}. \tag{I.17}$$

Given (II.6), the nominal wage for effective labor evolves according to

$$W_t = \left[\theta_w (W_{t-1})^{1-\psi_l} + (1-\theta_w)(\hat{w}_t)^{1-\psi_l}\right]^{\frac{1}{1-\psi_l}}.$$

4.2 Firms

The economy features two sectors. The first sector, denoted by superscript $j = d$, produces a domestic good that importing firms combine with imports to a final good. The final good can then be used for either final consumption, intermediate consumption or capital. The second sector, denoted by superscript $j = x$, produces an export good for the foreign market. Both sectors use varieties as inputs. These varieties are specific to each of the two sectors. They are produced using capital, labor and intermediate goods as inputs. I start by describing the production of the two sector goods. Both domestic and export goods are produced in the same way, but I will distinguish between the two sectors when discussing the firms' pricing behavior.

Sector Goods

Production of the sector goods occurs in two stages. As I did with the supply of labor above, I employ a two-stage production process, which allows me to use a Calvo price setting mechanism. In the first stage, monopolistically competitive firms in each sector produce differentiated "varieties" which are used as inputs into the assembly of the sector good. In the second stage, competitive sector goods firms produce the sector good from a CES combination of the varieties. These firms then sell the sector good at the nominal price p_t^j. I describe the two-stage process of production in reverse, starting with the second stage.

Second Stage The second stage producers assemble the sector good from the varieties. They are competitive in both the market for their output and the market for their inputs. They solve the following maximization problem

$$max_{y_t^j(\xi)} \left\{ p_t^j y_t^j - \int_0^1 \varphi_t^j(\xi) \, y_t^j(\xi) \, d\xi \right\}$$

subject to the CES production function

$$y_t^j = \left[\int_0^1 y_t^j(\xi)^{\frac{\upsilon-1}{\upsilon}} \, d\xi \right]^{\frac{\upsilon}{\upsilon-1}}.$$

Here y_t^j is the real quantity of sector goods produced at time t. The indexing variable ξ indexes the continuum of differentiated types of variety producers (thus ξ is one of the varieties). The parameter $\upsilon > 1$ governs the degree of substitutability across varieties. The date t nominal price of each variety is $\varphi_t^j(\xi)$ and the quantity of each variety is $y_t^j(\xi)$. It is straight-forward to show that the demand for each variety has an iso-elastic form

$$y_t^j(\xi) = y_t^j \left(\frac{\varphi_t^j(\xi)}{p_t^j} \right)^{-\upsilon}. \tag{I.18}$$

The competitive price of the sector good p_t^j is then a combination of the prices of the varieties. In particular, for the domestic good, all prices are set in domestic currency, so that the price is

$$p_t^d = \left[\int_0^1 \varphi_t^d(\xi)^{1-\upsilon} \, d\xi \right]^{\frac{1}{1-\upsilon}}. \tag{I.19}$$

A share ϕ_X of variety producers in the export market set their price in foreign currency, \$ (dollars). The exchange rate to convert dollars into Estonian kroons is $\frac{E}{E_\$}$, where $E_\$$ is the exchange rate of dollars vis-a-vis euros and its units are dollars over euros. Let the price of variety producer ξ that invoices in Estonian kroons be denoted $\varphi^x_{\$,t}(\xi)$ and the price of variety producer ξ that invoices in Estonian kroons, k, be denoted $\varphi^x_{k,t}(\xi)$. Then, the competitive price in the export market, converted into domestic currency is

$$p^x_t = \left[\frac{E_{\$,t}}{E_t} \int_0^{\phi_X} \varphi^x_{\$,t}(\xi)^{1-\upsilon} d\xi + \int_{\phi_X}^1 \varphi^x_{k,t}(\xi)^{1-\upsilon} d\xi \right]^{\frac{1}{1-\upsilon}}. \tag{I.20}$$

First Stage The varieties $y^j_t(\xi)$ which are used to assemble the sector good y^j_t are produced in the first stage. The first-stage producers rent effective units of capital k^j_t at the nominal rental price R^j_t, hire workers l^j_t at the nominal wage W_t, and purchase intermediate goods q^j_t at the nominal price P_t for use in production. Unlike the firms in the second stage, the first-stage, variety producers are monopolistically competitive. They seek to maximize profits taking the demand curve for their product (II.7) as given. These firms each have access to a Cobb-Douglas production function

$$y^j_t(\xi) = Z^j \left(\left[k^j_t(\xi)\right]^\alpha \left[l^j_t(\xi)\right]^{1-\alpha} \right)^\gamma \left(q^j_t(\xi)\right)^{1-\gamma}.$$

Because the first-stage producers are monopolistically competitive, they typically charge a markup for their products. The desired price naturally depends on the demand curve (II.7). Each type of variety producer ξ freely chooses capital, labor and intermediate goods each period, but there is a chance that their nominal price $\varphi^j_t(\xi)$ is fixed to some preset level. In this case, the first-stage producers choose an input mix to minimize costs taking the date t price $\varphi^j_t(\xi)$ as given. Cost minimization implies that

$$
\begin{aligned}
R_t^j &= MC_t^j \frac{\alpha y_t^j}{k_t^j(\xi)} \\
W_t &= MC_t^j \frac{(1-\alpha)\gamma}{l_t^j(\xi)} \\
P_t &= MC_t^j (1-\gamma) \frac{y_t^j(\xi)}{q_t^j(\xi)},
\end{aligned}
$$

where MC_t^j is the marginal cost of production. The factor input ratios are constant for all of the variety producing firms in sector j, in particular

$$
\begin{aligned}
\frac{k_t^j(\xi)}{l_t^j(\xi)} &= \frac{\alpha}{1-\alpha} \frac{W_t}{R_t^j} = \frac{u_t^j K_t^j}{L_t^j} \\
\frac{q_t^j(\xi)}{d_t^j(\xi)} &= \frac{1-\gamma}{\gamma} \frac{\left(\frac{R_t^j}{\alpha}\right)^{\alpha} \left(\frac{W_t}{1-\alpha}\right)^{1-\alpha}}{P_t} = \frac{Q_t^j}{\left(u_t^j K_t^j\right)^{\alpha} \left(L_t^j\right)^{1-\alpha}}
\end{aligned}
$$

where u_t^j denotes the utilization level and $d_t^j(\xi) = \left[k_t^j(\xi)\right]^{\alpha} \left[l_t^j(\xi)\right]^{1-\alpha}$ is the aggregate of capital and labor. This implies that (within any sector j) the nominal marginal cost of production is constant across the variety producing firms. Nominal marginal costs can be equivalently expressed in terms of the underlying nominal input prices W_t, R_t^j and P_t.

$$
MC_t^j = \frac{\left(W_t^{1-\alpha}\left(R_t^j\right)^{\alpha}\right)^{\gamma} P_t^{1-\gamma}}{Z^j} \left[\left(\frac{1}{\gamma(1-\alpha)}\right)^{1-\alpha} \left(\frac{1}{\gamma\alpha}\right)^{\alpha}\right]^{\gamma} \left(\frac{1}{1-\gamma}\right)^{1-\gamma}.
$$

Pricing I first discuss the pricing mechanism for domestic currency pricing. I then point out the difference for foreign currency pricing.

The nominal prices of the varieties are adjusted only infrequently according to the standard Calvo mechanism. I let $\varphi_t^j(\xi)$ denote the nominal price of variety producer ξ that prevails at time t in sector j. In particular, for any firm, there is a fixed probability θ_p that the firm cannot change its price that period. When a firm can reset its price, it chooses an optimal reset price. Because the production functions have constant returns to scale, and because the firms are competitive in the input markets, all firms ξ that can reset their price at time t optimally choose the same reset price $\hat{\varphi}_t^j(\xi) = \hat{\varphi}_t^j$. The reset price is chosen to maximize the discounted value of profits. Firms act in the interest of the representative household in their country so they apply the household's stochastic discount factor to all future income streams. The maximization problem of a firm that can reset its price at date t is

$$\max_{\hat{\varphi}_t} \sum_{r=0}^{\infty} (\theta_p \beta)^r \sum_{s^{t+r}} \pi(s^{t+r}|s^t) \frac{U_{1,t+r}}{P_{t+r}} \left(\hat{\varphi}_t^j - MC_{t+r}^j\right) y_{t+r}^j \left(\frac{\hat{\varphi}_t^j}{p_{t+r}^j}\right)^{-\upsilon}.$$

The solution to this optimization problem requires

$$\hat{\varphi}_t^j = \frac{\upsilon}{\upsilon - 1} \frac{\sum_{r=0}^{\infty} (\theta_p \beta)^r \sum_{s^{t+r}} \pi(s^{t+r}|s^t) \frac{U_{1,t+r}}{P_{t+r}} \left(p_{t+r}^j\right)^{\upsilon} MC_{t+r}^j y_{t+r}^j}{\sum_{r=0}^{\infty} (\theta_p \beta)^r \sum_{s^{t+r}} \pi(s^{t+r}|s^t) \frac{U_{1,t+r}}{P_{t+r}} \left(p_{t+r}^j\right)^{\upsilon} y_{t+r}^j}.$$

Because the variety producers adjust their prices infrequently, the nominal price of the sector goods are sticky. For the domestic producers, all prices are sticky in domestic currency. Then, using (I.19), the nominal price of the domestic good evolves according to

$$p_t^d = \left[\theta_p \left(p_{t-1}^d\right)^{1-\upsilon} + (1-\theta_p) \left(\hat{\varphi}_t^d\right)^{1-\upsilon}\right]^{\frac{1}{1-\upsilon}}. \tag{I.21}$$

Variety producers in the export sector either invoice in domestic currency, kroons, or foreign currency, dollars. Those producers invoicing in kroons face a similar problem as the firms in the domestic sector. Those invoicing in dollars maximize the discounted value of profits in kroons:

$$\max_{\hat{\varphi}_{\$,t}^x} \sum_{r=0}^{\infty} (\theta_p \beta)^r \sum_{s^{t+r}} \pi(s^{t+r}|s^t) \frac{U_{1,t+r}}{P_{t+r}} \left(\frac{E_{t+r}}{E_{\$,t+r}} \hat{\varphi}_{\$,t}^x - MC_{t+r}^x\right) y_{t+r}^x \left(\frac{E_{t+r}}{E_{\$,t+r}} \frac{\hat{\varphi}_{\$,t}^x}{p_{t+r}^x}\right)^{-\upsilon}$$

and the solution requires:

$$\hat{\varphi}_{\$,t}^x = \frac{\upsilon}{\upsilon - 1} \frac{\sum_{r=0}^{\infty} (\theta_p \beta)^r \sum_{s^{t+r}} \pi(s^{t+r}|s^t) \frac{U_{1,t+r}}{P_{t+r}} \left(\frac{E_{\$,t+r}}{E_{t+r}} p_{t+r}^x\right)^{\upsilon} MC_{t+r}^x y_{t+r}^x}{\sum_{r=0}^{\infty} (\theta_p \beta)^r \sum_{s^{t+r}} \pi(s^{t+r}|s^t) \frac{U_{1,t+r}}{P_{t+r}} \frac{E_{t+r}}{E_{\$,t+r}} \left(\frac{E_{\$,t+r}}{E_{t+r}} p_{t+r}^x\right)^{\upsilon} y_{t+r}^x}.$$

Then, using (I.20) the price index for exporters can be split up into two parts:

$$p_t^x = \left[\phi_X \left(\frac{E_t}{E_{\$,t}} p_{\$,t}^x\right)^{1-\upsilon} + (1-\phi_X)\left(p_{k,t}^x\right)^{1-\upsilon}\right]^{\frac{1}{1-\upsilon}}, \tag{I.22}$$

where the price of dollar-invoicing firms evolves according to

$$\left(p_{\$,t}^x\right)^{1-\upsilon} = \theta_p \left(p_{\$,t-1}^x\right)^{1-\upsilon} + (1-\theta_p)\left(\hat{\varphi}_{\$,t}^x\right)^{1-\upsilon}$$

and that of kroon-invoicing firms follows

$$\left(p_{k,t}^x\right)^{1-\upsilon} = \theta_p \left(p_{k,t-1}^x\right)^{1-\upsilon} + (1-\theta_p)\left(\hat{\varphi}_{k,t}^x\right)^{1-\upsilon}.$$

Imports

Importing firms bundle imported goods and domestically produced goods to a final good using a CES production function. The price of the imported goods in Estonian kroons is $\frac{E_t p_t^m}{E_{\$,t}}$. Domestic goods are purchased at price p_t^d. Then, importers solve the following maximization problem

$$max_{y_t^d, y_t^m} \left\{ P_t Y_t - p_t^d y_t^d - \frac{E_t p_t^m}{E_{\$,t}} y_{i,t}^m \right\}$$

subject to the CES production function

$$Y_t = \left((1-\omega)^{\frac{1}{\psi}} \left(y_t^m\right)^{\frac{\psi-1}{\psi}} + \omega^{\frac{1}{\psi}} \left(y_t^d\right)^{\frac{\psi-1}{\psi}}\right)^{\frac{\psi}{\psi-1}}. \tag{I.23}$$

The parameter ψ governs the degree of substitutability between domestically produced and imported goods. The expenditure share on domestic goods is $0 \leq \omega \leq 1$.

Demand for domestically produced goods is:

$$y_t^d = Y_t \omega \left[\frac{p_t^d}{P_t}\right]^{-\psi}.$$

Similarly, demand for imported goods is:

$$y_t^m = Y_t(1-\omega)\left[\frac{E_t p_t^m}{E_{\$,t} P_t}\right]^{-\psi}. \tag{I.24}$$

The implied nominal prices of the final good Y_t is

$$P_t = \left((1-\omega)\left(\frac{p_t^m E_t}{E_{\$,t}}\right)^{1-\psi} + \omega\left(p_t^d\right)^{1-\psi}\right)^{\frac{1}{1-\psi}}.$$

Since importing firms have production functions with constant returns to scale and they behave competitively, their profits are zero in equilibrium.

Pricing Pricing of imported goods is analogous to the pricing of exports. In particular, I assume that exporters to Estonia solve a similar maximization problem to Estonian exporters. The price index for their exports to Estonia is

$$p_t^m = \left[(1-\phi_M)\left(\frac{E_{\$,t}}{E_t} p_{k,t}^m\right)^{1-\upsilon} + \phi_M\left(p_{\$,t}^m\right)^{1-\upsilon}\right]^{\frac{1}{1-\upsilon}}, \tag{I.25}$$

with

$$\left(p_{k,t}^m\right)^{1-\upsilon} = \theta_p\left(p_{k,t-1}^m\right)^{1-\upsilon} + (1-\theta_p)\left(\hat{\varphi}_{k,t}^m\right)^{1-\upsilon}$$

and

$$\left(p_{\$,t}^m\right)^{1-\upsilon} = \theta_p\left(p_{\$,t-1}^m\right)^{1-\upsilon} + (1-\theta_p)\left(\hat{\varphi}_{\$,t}^m\right)^{1-\upsilon}.$$

Their optimal export price in dollars $\hat{\varphi}_{\$,t}^m$ is exogenous and constant.

4.3 Foreign Demand

I model foreign demand as in Kehoe and Ruhl (2009). Although Estonia is small in the sense that it takes world interest rates as given, it faces a downward-sloping demand curve for its products. I assume that foreign countries use a similar CES production function to produce their final goods, which require imports from Estonia. Then, their demand for Estonian imports is

$$y_t^x = \left[\frac{E_{\$,t} p_t^x}{E_t P_{\$,t}^*} \right]^{-\psi} Y_t^*, \tag{I.26}$$

where Y_t^* denotes foreign real absorption and $P_{\$,t}^*$ the corresponding price deflator in foreign currency.

4.4 Monetary Policy

The nominal interest rate on euro-denominated bonds, $i_t^{€}$, is exogenous and constant. The monetary authority of the small open economy uses the domestic interest rate i_t as its policy instrument. It maintains the currency peg to the euro and therefore sets its interest rate such that $\Delta E_t = 0 \; \forall t$.

4.5 Aggregation and Market Clearing

Market clearing For each sector j, aggregate production of the sector goods is (up to a first-order approximation) given by

$$y_t^j = Z^j \left(\left[u_t^j K_t^j \right]^\alpha \left[L_t^j \right]^{1-\alpha} \right)^\gamma \left(Q_t^j \right)^{1-\gamma}.$$

Production of the final good is given by (I.23). Its market clearing condition is

$$Y_t = C_t + \sum_j \left(X_t^j + Q_t^j + a(u_t^j) K_t^j \right). \tag{I.27}$$

Market clearing for the domestic bond requires

$$B_t = 0. \tag{I.28}$$

Definitions Employment, total investment and total intermediate consumption are defined as $L_t = \sum_j L_t^j$, $X_t = \sum_j X_t^j$, $Q_t = \sum_j Q_t^j$.

Nominal GDP in this economy is

$$NGDP_t = p_t^d y_t^d + p_t^x y_t^x - P_t Q_t = P_t \left(C_t + X_t + \sum_j \left(a(u_t^j) K_t^j \right) \right) + p_t^x y_t^x - \frac{E_t}{E_{\$,t}} p_t^m y_t^m.$$

I define real GDP using steady-state prices. Fluctuations in real GDP are therefore driven by changes in real quantities, but not in relative prices. Finally, inflation and wage inflation are defined as the gross change in the price of the final good $\pi_t = \frac{P_t}{P_{t-1}}$ and the gross change in the wage $\pi_t^W = \frac{W_t}{W_{t-1}}$.

4.6 Definition of Equilibrium

An equilibrium of this economy is defined as intertemporal sequences of allocations $\left\{C_t, L_t^j, X_t^j, K_t^j, u_t^j, Q_t^j, y_t^j, y_t^m, B_t, B_t^{€}\right\}_{t=0}^{\infty}$ for $j = d, x$ and prices $\left\{P_t, E_t, p_t^d, p_{\$,t}^x, p_{k,t}^x, p_t^m, \hat{\varphi}_t^d, \hat{\varphi}_{\$,t}^x, \hat{\varphi}_{k,t}^x, W_t, R_t^j, MC_t^j, \nu_t^j\right\}_{t=0}^{\infty}$ for $j = d, x$ that solve the household's problem and the problem of each representative firm, and that satisfy the market clearing conditions (I.27) and (I.28), for given initial conditions $\left\{K_0^j, B_0^{€}, p_0^d, p_{\$,0}^x, p_{k,0}^x, W_0\right\}$ and intertemporal sequences of exogenous variables $\left\{Y_t^*, E_{\$,t}, i_t^{€}, P_{\$,t}^*, \hat{\varphi}_{\$,t}^m\right\}_{t=0}^{\infty}$. In my quantitative analysis I focus on equilibria that start from initial conditions calibrated to match the Estonian economy at a stationary equilibrium in 2002 before the accession to the EU. The precise specfication of these intial conditions is described in the next section.

5 Quantitative Analysis

In this section, I analyze my model's response to a currency devaluation. I consider a counterfactual experiment of a 10 percent currency devaluation. Such a devaluation would have raised Estonia's GDP by more than 5 percent upon impact. I explain that this strong reaction in GDP can be attributed to a large expansion of the non-traded sector. I conclude by drawing more general lessons from my model by comparing alternative parameterizations.

5.1 Calibration

My model is calibrated at annual frequency. Here, I discuss the calibrated parameters that are summarized in Table I.5. Most parameters are calibrated to match ratios observed in 2002, before Estonia entered the boom and bust cycle.

I set the coefficient of relative risk aversion to $\sigma = 2$, the standard value in the IRBC literature. I assume a unit elasticity of labor supply, i.e $\eta = 1$. This a conventional value for the labor supply elasticity (see e.g. Gorodnichenko et al. (2012)) and is in line with evidence provided by Hall (2007) for the U.S.

I use my estimate of the Calvo price rigidity parameter $\theta_p = 0.59$. This ensures that a 1 percent exchange rate change leads to a price change of 0.41 percent within a year, as observed in my data. There is some evidence that wages are somewhat more rigid than prices (see Dabušinskas and Rõõm, 2011). I therefore set $\theta_w = 0.65$. My model results are somewhat sensitive to the values for θ_p and θ_w and I therefore later evaluate my model at alternative values for these parameters.

I calibrate the markup $\mu = \frac{\upsilon-1}{\upsilon}$ to match a profit to GDP ratio of 10 percent. The resulting markup is 4.5 percent.[24]

I choose the two production parameters, γ and α, to match the share of intermediate con-

[24]New Keynesian DSGE models without intermediate goods set the elasticity of substitution between subsector goods to values between 7 and 12 (see e.g. Christiano et al., 2014 or Del Negro et al., 2013). This corresponds to a profit to GDP ratio of roughly 9-15%.

sumption in total production (0.58 in 2002) and the labor share (0.55). I take into account that sub-sector firms earn profits because they are not perfectly competitive. In particular, $1-\gamma$ is measured as the share of intermediate consumption in total production, augmented by the markup: $1-\gamma=\mu\frac{Q}{Y}$. Similarly, $1-\alpha$ corresponds to the labor share adjusted for a markup and the intermediate consumption share: $1-\alpha=\frac{WL}{GDP}\frac{\mu-1+\gamma}{\gamma}$. The labor share $\frac{WL}{GDP}$ is calculated as the ratio of compensation of employment and gross value added, both in nominal terms. Compensation of employment is compensation of employees times the ratio of total hours worked to hours worked by employees.

I calibrate the depreciation rate to the investment to GDP ratio in Estonia in 2002. This ratio was about 0.25, which results in a depreciation rate of 10%.

I choose a low value for the investment adjustment cost parameter, $f_K''=2.48$, which sufficiently reduces the volatility of investment. I set the utilization cost parameter to $h=0.08$, which is in the range of other RBC models (e.g. Christiano et al., 2014).

I choose a value of 1.5 for the trade elasticity ψ, which is in the range of my empirical estimates, lying between 1 (for small firms) and 2 (for large firms).

Estonia's average trade over GDP ratio has been rising from 62 percent in 2002 to 88 percent in 2012. I calibrate ω to an average trade share of 75 percent.

The share of firms invoicing in foreign currency is calibrated to my firm-level data. In my dataset, roughly 17 percent of the value of exports and 15 percent of the value of imports in 2009 is invoiced in Estonian kroons. Those ratios have been constantly declining over the sample period. I choose values for 2009 because my counterfactual experiments analyze a currency devaluation during the recession in 2009.

5.2 Response to an Exchange Rate Devaluation

In this section, I discuss the model-implied response to an exchange rate devaluation and explain why the general equilibrium response is stronger than the partial equilibrium response observed in the firm-level data.

TABLE I.5: CALIBRATION

Preferences			
Discount factor	β	0.96	Standard value
Coefficient of relative risk aversion	σ	2	Standard value
Frisch elasticity of labor supply	η	1	in line with Hall (2007)
Technology			
Production coefficient capital	α	0.39	Labor share: $\frac{WL}{GDP} = 0.55$, Stat Est
Production coefficient value added	γ	0.39	Intermediate share: $\frac{Q}{Y} = 0.58$, Stat Est
Depreciation rate	δ	0.10	Investment to GDP ratio: $\frac{X}{GDP} = 0.25$, Stat Est
Markup	μ	1.045	Profit share $\frac{\Pi}{GDP} = 0.10$
Utilization cost	a''	0.08	Christiano et al. (2014)
Sticky price probability	θ_p	0.59	Own estimate based on firm-level data
Sticky wage probability	θ_w	0.65	Dabušinskas and Rõõm (2011)
Capital investment adjustment cost	f''_K	2.48	Christiano et al. (2005)
Trade			
Armington elasticity	ψ	1.5	Own estimate based on firm-level data
Aggregate import share	$1-\omega$	0.32	Trade to GDP ratio: $\frac{y^x+y^m}{2GDP} = 0.75$, Stat Est
Share foreign currency pricing exports	ϕ_X	0.83	Firm-level data
Share foreign currency pricing imports	ϕ_X	0.85	Firm-level data

Notes: Stat Est stands for Statistics Estonia. OECD QNA are the OECD Quarterly National Accounts.

I solve the model by log-linearizing the first order conditions around the deterministic steady state.[25] I then shock the economy with a 10 percent devaluation. The solid blue line in the upper left panel of Figure I.4 displays the resulting impulse response for GDP. The remaining three panels show the impulse response of the sum of consumption and investment, exports and imports, all measured in percent of GDP. The figure also decompose the total effect into an effect driven by changes in the export exchange rate and an effect driven by changes in the import exchange rate, as I did in my empirical analysis. The export exchange rate effect is based on a counterfactual experiment where only the exchange rate affecting exports is devalued, and similarly for the import exchange rate effect. In my model, these two effects sum up to the total (net) effect.

The model shows that the general equilibrium response to a devaluation is significantly larger than the partial equilibrium response observed in the data. Following a 10 percent devaluation, GDP increases by 5.2 percent upon impact and remains 3 percent above trend after 3 years. The increase in GDP is driven by an expansion of domestic absorption (55 percent) and an expansion of net exports (45 percent).

What explains this relatively strong response in the model? First, the decomposition into an export effect and an import effect shows that the model implies an *expansion* after a devaluation of the import exchange rate, in contrast to the firm-level data. As the import exchange rate depreciates, imports become more expensive, which leads to two effects: On the one hand, the higher input costs make production less profitable and firms reduce their production (*import cost effect*). On the other hand, demand for relatively cheap domestic goods increases and stimulates production (*import substitution effect*). In the short run, the import substitution effect dominates because prices are sticky: The import cost effect is small because firms relying on imports cannot raise their price in response to higher marginal costs and keep on producing, albeit at reduced profit rates. The import substitution effect is particularly strong because domestic prices do not adjust in the short run and domestic goods remain cheap compared to imports. Figure I.4

[25] See the appendix sections Appendix B for the steady state.

shows that the import cost channel starts dominating in the medium run: the import effect turns negative in the ninth year after the devaluation.

Second, households frontload consumption in response to an exchange rate devaluation. A 10 percent devaluation requires an increase of nominal prices by 10 percent in the long run, so that the real exchange rate returns to its steady-state level. A devaluation therefore raises inflation expectations and households, in expectation of higher prices in the future, raise their consumption. The increase in consumption (and investment) account for roughly 55 percent of the increase in GDP.

These two factors—the intratemporal substitution effect and the intertemporal substitution effect—stimulate production of firms in the non-traded sector and therefore raise total production in the economy.

The effects of a devaluation on GDP remain large in the medium run. In 2011, the third year after the devaluation, GDP is 3 percent higher than without the devaluation. This medium-run effect is driven by the increase in exports and subsequent higher demand for intermediates. The rise in exports is lagged because a large share of Estonian exporters invoice in foreign currency. Upon impact of a devaluation, exporters invoicing in foreign currency see little increase in the demand for their products because their prices are sticky. Over time, they adjust their foreign currency prices downwards, in line with their lower marginal costs. This stimulates demand and production, which explains the overall persistence of the devaluation.

5.3 Devaluations, Nominal Rigidities and Trade Openness

Here, I discuss whether my results are specific to the Estonian economy in 2009 and how they might apply to other countries.

The response of GDP to a currency devaluation mainly depends on the extent to which prices and wages are sticky, the trade elasticity, the size of the export sector and the share of trade that is invoiced in foreign currency. Figure I.5 displays the short-run elasticity of GDP as a function of these parameters. In my benchmark calibration, this elasticity is 0.52. The black dashed line

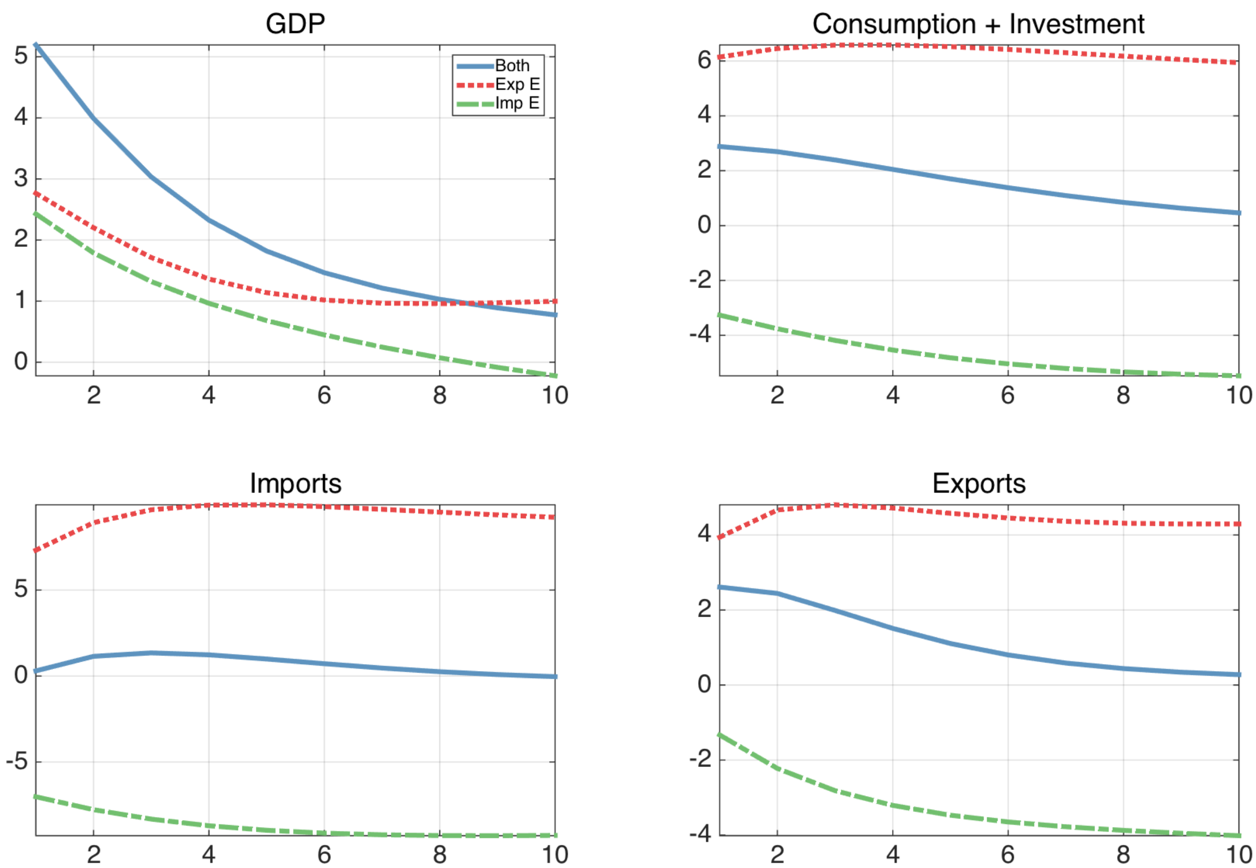


Figure I.4: Elasticity of Main Aggregates to Exchange Rate Devaluation

Note: The figure displays the response of GDP to a 10 percent devaluation of the Estonian kroon (upper left panel). It also breaks up the GDP response into the sum of consumption and investment (upper right panel), exports (lower right panel) minus imports (lower left panel). Responses are deviations from steady state, measured in percent of GDP.

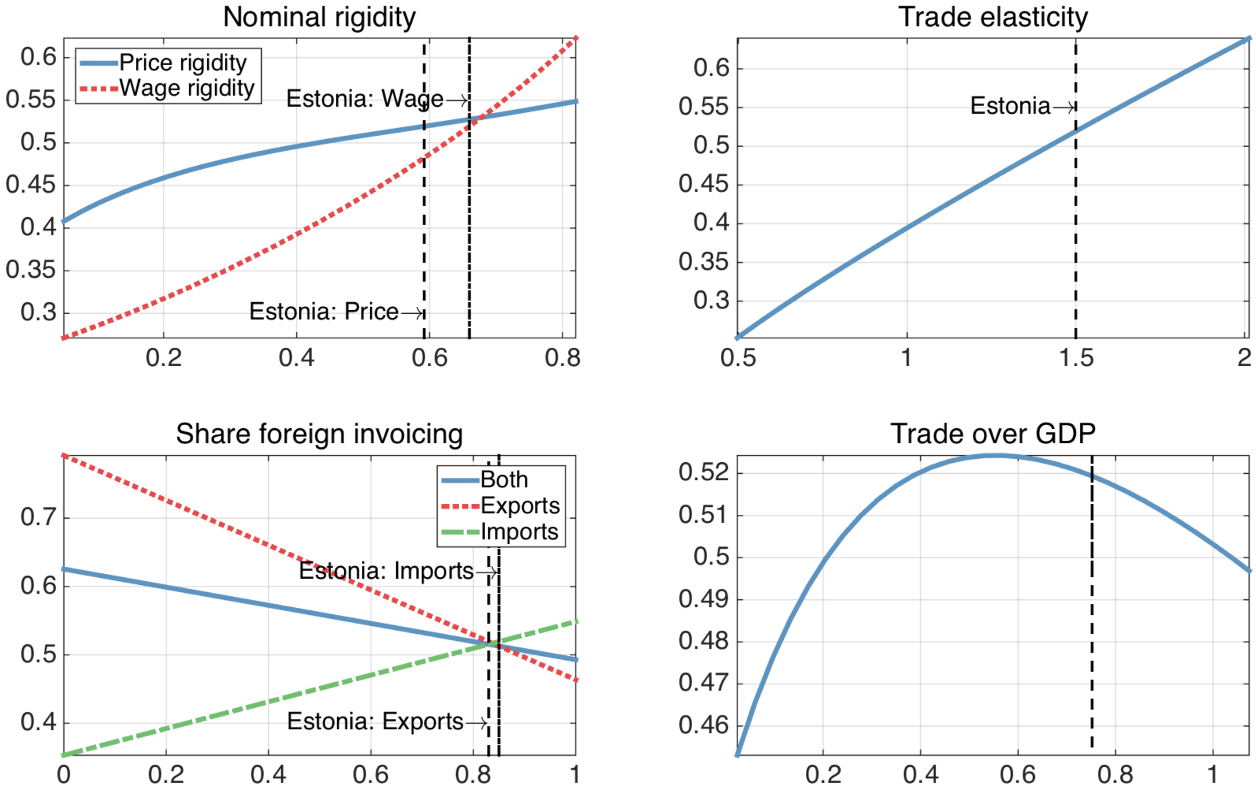


Figure I.5: Elasticity of GDP to Exchange Rate Devaluation: Varying Parameters

Notes: The figure displays the elasticity of GDP to a nominal exchange rate devaluation as a function of various parameters. The elasticity is calculated as the percent deviation from steady state in the first year after the devaluation. The elasticity is depicted on the y-axis. The x-axis depicts variations in a parameter, keeping all other parameters at their benchmark level given in Table I.5. 'Nominal rigidity' varies θ_p (price rigidity) or θ_w (wage rigidity). 'Trade elasticity' varies ϕ. 'Share foreign invoicing' varies the share of foreign currency invoicing, either for both exports (ϕ_X) and imports (ϕ_M) (blue solid line), or exports only (red dotted line) or imports only (green dashed line). 'Trade over GDP' varies ω. The x-axis depicts the ratio of trade to GDP. The benchmark parameter for Estonia is marked by a blacked dashed line.

in each plot corresponds to this benchmark value.

The first subplot reveals that the response of GDP is smaller in countries with more flexible prices and wages. It also shows that price rigidity matters less than wage rigidity. The reason is as follows: Sticky prices keep domestic prices low and reinforce the import substitution effect, which stimulates the production of non-traded goods. The response of GDP is therefore stronger when prices are more sticky. But a second effect weakens this relationship: sticky prices hinder the expansion of exports when the share of exports invoiced in foreign currency is high. As discussed above, exporters invoicing in foreign currency want to lower their foreign currency prices because their marginal costs are temporarily low. This would stimulate their exports. When prices are sticky, exporters cannot lower their price and GDP will respond less to a devaluation. These two effects—sticky prices reinforcing the import substitution effect, but weakening the export competition effect—work in opposite direction. Hence, the degree to which prices are sticky has less impact on a country's response to a devaluation when most of that country's exports are invoiced in foreign currency and exports are a large share of GDP. This is important because most countries with pegged exchange rates are small and invoice their exports in foreign currency (see Gopinath, 2015).

The second subplot shows that countries trading goods with higher demand elasticities would benefit more from a devaluation because a high elasticity facilitates expenditure switching from foreign to domestically produced goods. Firm-level studies suggest that an elasticity in the range of 0.5 to 2 might be reasonable for most countries.[26] In that range, the response of GDP to a 1 percent devaluation varies between 0.25 and 0.65.

The invoicing currency composition of Estonia's trade shows that almost 85 percent of trade is invoiced in foreign currency. Countries like Sweden, Norway and Switzerland have foreign invoicing shares around 60 percent (see Gopinath, 2015). My model predicts a somewhat larger response of GDP to currency depreciation in those countries with smaller foreign invoicing shares. If more exports are invoiced in domestic currency, a devaluation leads to a stronger reduction in the export price, quoted in foreign currency. This increases the export competition effect. At the same time, a higher share of imports invoiced in domestic currency reduces the import substitution effect. The net effect of a lower foreign invoicing share is slightly positive. Monetary policy is therefore less effective in countries where most trade is invoiced in foreign currency.

The last subplot shows that the effects of devaluations are almost orthogonal to a country's trade openness. This somewhat surprising result follows from the discussion in the previous section. Under my calibration, both the domestic and the export sector expand at roughly equal rates. Changing their relative size therefore has little impact on the overall expansion of GDP.

[26] For instance, Cravino (2014) finds a trade elasticity of 1-2 for Chilean firms, Dekle and Ryoo (2007) find estimates around 1 for Japan, Campa (2004) finds an estimate of 0.7 for Spain, Fitzgerald and Haller (2014) report an estimate of 0.8 for Ireland, and Berman et al. (2012) find an estimate of 0.4 for France

This result hinges on my calibration to the Estonian economy. For example, for countries with a larger trade elasticity, the expansion of the export sector dominates the expansion of the domestic sector, so that the effects of a devaluation increase in the country's trade openness.

To sum up, this section has shown that devaluations are expected to be more expansionary in countries with sticky wages and prices, a high trade elasticity and a low share of foreign currency invoicing.

6 Conclusion

In this paper, I analyze whether exchange rate changes affect economic performance. I find empirical evidence that firms expand in response to exchange rate depreciations in their export market and exchange rate appreciations in their import market. The elasticity of output with respect to the export exchange rate is between 1.25 and 2, whereas it is between -0.5 and -1.5 with respect to the import exchange rate.

I then ask whether a currency devaluation would have helped the Estonian economy during the Great Recession. This experiment only looks at the price effects of an exchange rate change, obviously ignoring other costs of leaving the peg, such as negative balance sheet effects and a potential capital flight. Based on my firm-level estimates, I calculate a modest expansionary effect of 1 to 2 percent in revenue in the traded sector for a 10 percent devaluation. This effect appears small, but is explained by a large share of trade invoiced in foreign currency, which reduces the export expansion effect and reinforces the import cost effect of a devaluation. I then set up a New Keynesian small open economy model to analyze the aggregate effects of a devaluation. The model predicts a much larger increase for GDP, around 5 percent for a 10 percent devaluation. This larger effect is mainly the result of intra- and intertemporal substitution effects towards current non-traded goods, which my empirical firm-level estimates cannot pick up. My model therefore suggests that understanding the full impact of a currency devaluation requires a better measurement of how firms in the non-traded sector are affected by exchange rate changes.

In future work, I will extend my model to a 3-country model that incorporates both the Euro area and the rest of the world to evaluate an alternative policy experiment: a depreciation of the euro initiated by a more aggressive monetary policy of the European Central Bank. Whether a euro depreciation would have a stronger effect is unclear. On the one hand, more than 50 percent of Estonia's trade is with euro area countries and would therefore not directly benefit from the depreciation. On the other hand, the depreciation will raise overall GDP and demand for products in the euro area, which will also stimulate Estonia's economy.

Chapter II

Austerity in the Aftermath of the Great Recession[1]

1 Introduction

The economies in Europe contracted sharply and almost synchronously during the global financial crisis. In the aftermath of the crisis, however, economic performance has varied. An open question is whether the difference in outcomes is due to variations in the severity of external shocks, the policy reactions to the shocks or the economic conditions at the time of the crisis. A number of prominent economists, including Ben Bernanke, Paul Krugman and Amartya Sen, have attributed at least some of the slow rate of recovery to austerity policies that cut government expenditures and increased tax rates at precisely the time when faltering economies required stimulus. This paper constructs measures of austerity and asks whether austerity can in fact account for the divergence in national economic performance since the Great Recession.

Figure II.1 plots real per capita GDP for 29 countries, including the U.S., countries in the European Union, Switzerland, and Norway. The data is normalized so that per capita GDP is 100 in 2008:1 for every country. The figure also plots per capita GDP for the European aggregate.

[1]This chapter is collaborative work with Linda L. Tesar and Christopher L. House.

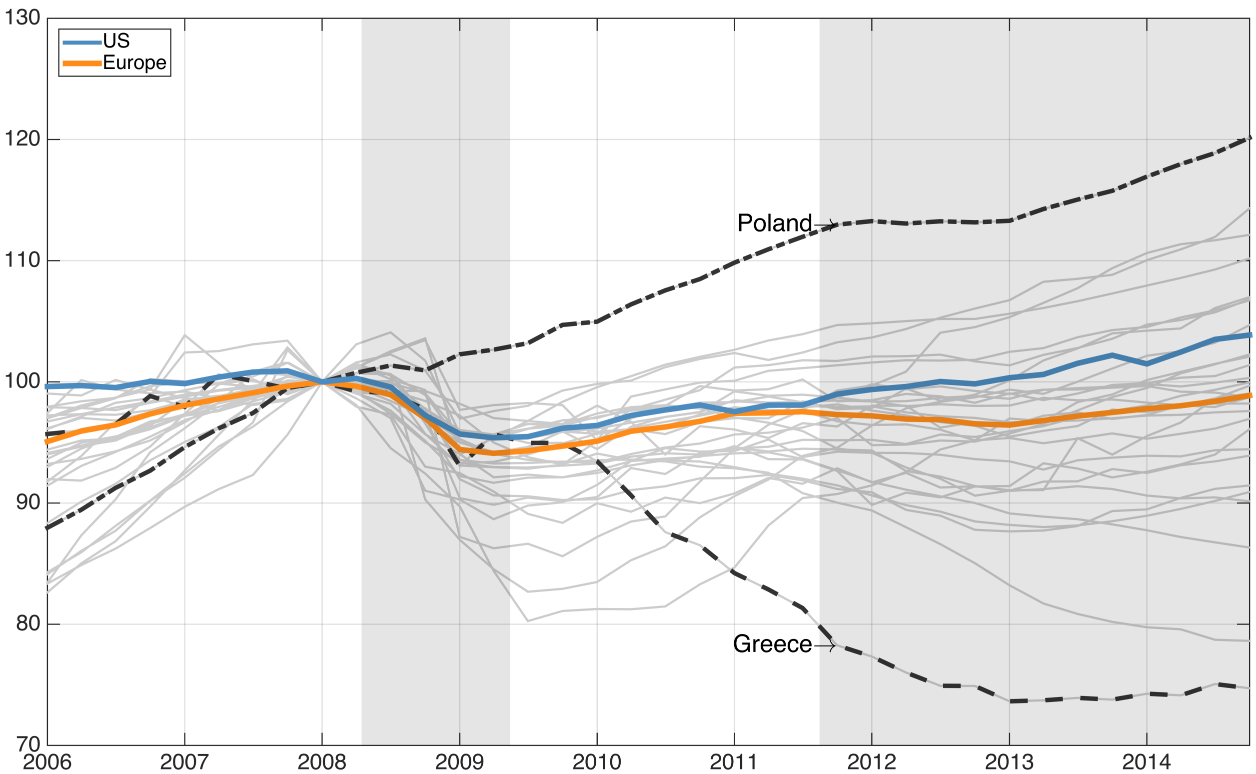


Figure II.1: Real per Capita GDP Before, During and After the Crisis

Note: The figure plots the time paths of real per capita GDP for the period 2006:1-2014:4 for the countries in our data set. The paths are indexed to 100 in 2008:1. The two shaded regions indicate recession dates according to the NBER and CEPR.

Overall, the aggregate European experience is similar to that of the United States. This similarity, however, masks a tremendous amount of variation across Europe. At one end of the spectrum is Greece for which the "recovery" never began. Greek per capita income at the end of 2014 is more than 25 percent below its 2008 level. While Greece's GDP performance is exceptionally negative, a contraction in GDP over this period is not unique. About a third of the countries in Figure II.1 have end of 2014 levels of real per capita GDP below their 2008 levels. At the other end of the spectrum is Poland. Unlike Greece, Poland experienced only a very modest contraction during the Great Recession and returned to a rapid rate of growth quickly thereafter.

Our goal is to document the cross-country differences in economic performance since 2010 and to study the extent to which the differences can be explained by macroeconomic policy. We do not attempt to explain the Great Recession and its transmission - rather, we focus on the divergence in the paths of economic recovery after the crisis. Our analysis proceeds in two steps. The first step is to construct measures of austerity shocks that occurred during the 2010 to 2014 period. We consider both spending-based measures of austerity and revenue-based measures of austerity. Both measures are constructed as (log) differences between observed spending (or revenues) and their predicted values. Using our methodology, we find that austerity in government outlays - a reduction in government spending that is larger than that implied by reduced-form forecasting regressions - is statistically associated with below forecast GDP. This is particularly true for government purchases, a subcategory of total government outlays. Our results suggest a multiplier on government purchases that is greater than 1. Revenues and the primary balance generally have a weak or no statistically significant relationship with our measures of economic performance. Therefore, we focus our empirical analysis and our theoretical model on the impact of changes in government purchases. The negative relationship between austerity in government purchases and GDP is robust to the method used to forecast both GDP and government purchases in the 2010 to 2014 period, and holds for countries with fixed exchange rates and flexible exchange rates. Austerity in government purchases is positively associated with net exports and the exchange rate (that is, a real appreciation), and negatively associated with GDP growth and inflation.

The second stage of our analysis develops a multi-country DSGE model to make direct comparisons between the observed empirical relationships and the model predictions. The model features trade in intermediate goods, sticky prices, sticky wages, and financial frictions that drive a wedge between the marginal product of capital and the frictionless user cost of capital. The model is calibrated to reflect relative country size, observed trade flows and financial linkages, and the country's exchange rate regime. The model incorporates austerity shocks, shocks to the cost of credit and monetary policy shocks. We focus on these three shocks because there is broad agreement that these factors played an important role in shaping the reaction to the Great Recession. We then compare the model predictions for GDP, inflation, net exports and the exchange rate with actual data in the 2010-2014 period.

Our benchmark model generates predictions that are broadly consistent with those seen in the data. In the cross-section, a regression of austerity in government purchases on GDP yields a coefficient of -0.30. That is, a one percent reduction in government spending is associated with a 0.30 percent reduction in GDP. In the analogous regression based on model-generated data, the coefficient is -0.17. The model is also successful in generating a positive relationship between austerity and net exports and the negative relationship between austerity and inflation and GDP growth. Austerity shocks are responsible for much of the observed variation in measures of economic activity in the model though monetary shocks are critical for generating realistic variation in nominal variables.

Given the success of the model in explaining cross-sectional macroeconomic performance we use the model as a laboratory for conducting a number of counterfactual experiments [to be completed]. For example, the model can be used to ask whether floating exchange rates, which permit for greater flexibility in monetary policy, might have supported a faster economic recovery in Europe.

2 Empirical Findings

We begin by characterizing the economic performance of European nations and the United States following the crisis. Our primary data sources are Eurostat and the OECD. The dataset includes all nations in the European Union with the exception of Croatia and Malta (excluded due to data limitations) and with the addition of Norway and Switzerland (outside of the European Union but members of the European Free Trade Association, EFTA). Our sample covers the period 1960 to 2014; it is an unbalanced panel due to limitations in data availability for some countries.

Table II.1 lists the countries in our data set together with each country's relative size, the share of imports in final demand (both averaged over 2005 and 2010) and the country's exchange rate regime as of 2010. Size is measured as the country's final demand (in nominal US dollars) relative to the sum of all European countries' final demand, where final demand is GDP less net exports. Country size varies from less than one percent of the European aggregate (e.g. Cyprus and Luxembourg) to over 100 percent (the U.S.). The import share is the share of imports in final demand. [2] The import share varies from a low of 13 percent in the U.S. to very high shares in Ireland and Luxembourg (44 percent and 57 percent, respectively). The average import share in Europe is 32 percent. The model in Section 3 will capture the extent of bilateral trade linkages between country pairs, as well as the overall openness to trade. Most countries in the sample have a fixed exchange rate because they are part of the euro area, or they have pegged their exchange rate to the euro. Nine have floating exchange rates.

2.1 Measuring Austerity

There are two conceptual issues in studying the impact of fiscal austerity on economic outcomes. One is that a policy can only be said to be austere relative to some benchmark. The second issue is the endogeneity of fiscal policy to the state of the economy – did a cut in government expenditures adversely affect output, or did government expenditures contract along with the decline

[2] We construct this share from the OECD Trade in Value Added database, as we explain later.

Table II.1: Country Size, Import Shares and Exchange Rate Regimes

Country	Size	Import share	XRT regime	Country	Size	Import share	XRT regime
Belgium	2.6 %	31.3 %	Euro	Bulgaria	0.3 %	40.3 %	Peg
Germany	18.3 %	24.3 %	Euro	Denmark	1.7 %	26.9 %	Peg
Ireland	1.1 %	44.2 %	Euro	Estonia	0.1 %	42.2 %	Peg
Greece	1.9 %	25.5 %	Euro	Latvia	0.1 %	36.8 %	Peg
Spain	8.4 %	24.1 %	Euro	Lithuania	0.2 %	32.2 %	Peg
France	15.3 %	21.2 %	Euro	Czech Republic	1.0 %	37.1 %	Floating
Italy	12.5 %	22.0 %	Euro	Hungary	0.7 %	38.9 %	Floating
Cyprus	0.1 %	39.5 %	Euro	Poland	2.5 %	28.8 %	Floating
Luxembourg	0.2 %	56.9 %	Euro	Romania	0.9 %	28.2 %	Floating
Netherlands	4.1 %	21.0 %	Euro	Sweden	2.4 %	28.8 %	Floating
Austria	2.1 %	30.3 %	Euro	United Kingdom	15.4 %	23.9 %	Floating
Portugal	1.4 %	28.3 %	Euro	Norway	1.9 %	25.3 %	Floating
Slovenia	0.3 %	38.1 %	Euro	Switzerland	2.8 %	31.7 %	Floating
Slovak Republic	0.4 %	41.5 %	Euro	United States	91.5 %	13.3 %	Floating
Finland	1.3 %	27.5 %	Euro	RoW	162.9 %	8.4 %	Floating

Notes: Table displays the 29 countries plus the Rest of the World in our sample. Size is measured as the country's final demand relative to the sum of all European countries' final demand. Final demand is measured as GDP less net exports, $\mathbb{N}_n Y_n$. Shares are averaged over 2005 and 2010. The import share is measured as the share of imports in final demand. The exchange rate regime is as of 2010. Countries with a peg have their currencies pegged to the Euro. Countries with a floating currency are either free or managed floaters or countries with a wide crawling peg. The classification follows Ilzetzki et al. (2004), $http://www.carmenreinhart.com/data/browse-by-topic/topics/11/$..

in output? A commonly adopted approach is to identify periods of austerity as episodes when, for example, the primary balance (the general government balance net of interest payments) decreases by a certain amount. Such data is available from the IMF and the OECD, often reported as a share of "cyclically-adjusted GDP" as a way of correcting for the current stage of the business cycle. This approach partially addresses the issue of defining austerity by picking an arbitrary cut off, but does not address endogeneity. An alternative is the narrative approach pioneered by Romer and Romer (2004). This method relies on a subjective assessment of the historical policy record to identify policy shifts that are motivated by long-run fiscal consolidation rather than the need for short-run temporary fiscal stimulus. The narrative approach addresses the endogeneity problem, though it requires a great deal of judgment in interpreting policy statements by government officials. The identified policy shifts may also reflect the intent of policymakers and not capture the policies that are ultimately enacted.

A third approach, and the one we adopt here, is to examine forecast errors in fiscal policy variables (government purchases, total outlays, total revenue and the primary balance) and their relationship with forecast errors in economic outcomes. We borrow heavily from Blanchard and Leigh (2013) who take a similar approach. However, rather than relying on forecasts generated by the IMF or national governments, we produce our own forecast measures. This gives us the flexibility to consider different methods of detrending and additional explanatory variables. Also, in addition to focusing on the reaction of GDP, we include the reactions of net exports, inflation, consumption, investment and the exchange rate in our analysis. We examine four basic measures of government austerity across countries: government purchases, total outlays, total revenue and the primary balance. Our preferred measure of government expenditure includes only the sum of final government consumption expenditure and government gross fixed capital formation (=government purchases). We also report results based on a broader measure of government expenditure that adds outlays for social benefits to government purchases (=total government outlays). Our measure of government revenue is the sum of tax receipts from consumption, capital and labor taxes (including mandatory social contributions to government health care and retirement programs). Finally, the primary balance is defined as total government revenue less total government outlays plus net interest payments.

Our preferred forecast specification for the austerity measures includes a country-specific time trend, contemporaneous GDP and its own lag. The forecast errors can be interpreted as departures from "normal" fiscal policy reactions to economic fluctuations. That is, if a country typically does not increase spending in the face of economic contractions and it continues that policy in the aftermath of the crisis, our procedure will dictate that that country is not austere. On the other hand, a country that typically responds to recessions by spending more but does not do so in the aftermath of the crisis will be interpreted as austere. Austerity “shocks” generated in this way are not econometrically exogenous. We do not have a valid instrument for government expenditure and revenue and for that reason, the empirical patterns we report must be interpreted cautiously. We focus on the observed, quantitative changes in policy variables and ask whether there is evidence that such changes are associated with changes in economic variables and whether the quantitative changes are large enough to explain observed variations in economic performance. While the shocks suffer from standard endogeneity problems, our preferred forecast specification does reduce one direct source of endogeneity by including contemporaneous GDP. Namely, we eliminate the direct connection between current economic activity and either spending or taxation. By including contemporaneous GDP in the forecast specification, the forecast errors report changes in spending or tax revenue that are not systematically related to the current state of the economy.

2.2 Constructing forecasts of austerity

For all variables, we construct reduced-form forecasts of what we would anticipate the variable to be given a set of information. The forecast equations are estimated on data prior to the crisis (1960, or the earliest available year, to 2005). We then construct out-of-sample residuals or forecast errors as the difference between predicted values and the actual values for the crisis period. The out-of-sample residuals can be interpreted as unusually high or low realizations of that variable relative to its predicted values. Though they are not identified structural shocks from an econometric point of view, we can still ask whether there is a correlation between the forecast errors of government policy and various measures of economic performance. In our analysis below, we will focus on the forecasts for the post-recession period 2010-2014. We treat the crisis as an anomalous period in that the forecasting regression does not use data during the crisis and we do not attempt to account for patterns in the data during the crisis.

Fiscal variables We consider four measures of fiscal austerity (the government purchases shortfall, the total outlays shortfall, total revenue, and the primary balance) for country i at date t.[3] The basic form of the forecast specification is given by equation (II.1) and includes country-specific time trends, lagged values of the log of G_t^i and the log of real per capita GDP.

$$\ln G_t^i = \beta_0^i + \beta_1^i t + \beta_2^i \ln G_{t-1}^i + \beta_3^i \ln GDP_t^i + \varepsilon_t^i. \tag{II.1}$$

Some countries report data for only a relatively short time span and therefore the estimated coefficients in the forecasting regression may be imprecise. To deal with this lack of precision, we follow two different approaches. The first approach is to use a two-stage "shrinkage" proceedure. The second approach is to replace our estimates for β_2^i by values commonly used in the literature.

For the two-stage shrinkage procedure, we start by estimating two different versions of (II.1). We first seperately estimate (II.1) by OLS for each country in our data. This produces a set of estimates $\hat{\beta}_j^{i,1}$ with standard errors $SE\left(\hat{\beta}_j^{i,1}\right)$. We then estimate (II.1) imposing the restriction that $\beta_2^i = \beta_2$ and $\beta_3^i = \beta_3$. That is, we assume that all nations have the same reaction to changes in log real per capita GDP and to lagged values of G_t^i. This produces estimates $\hat{\beta}_j^{i,\text{pool}}$ where the superscript indicates that the data are pooled to produce a common estimate. In the second

[3]Government purchases, totaly outlays and total revenue are deflated by the GDP deflator and in per capita terms. They are expressed in constant 2010 euros. We normalize the primary balance by dividing by a country's GDP in 2005. Also, we do not use the log for the primary balance, but the percent value of GDP.

stage we compute the convex combinations

$$\hat{\beta}_j^{i,2} = \frac{1}{\gamma + SE\left(\hat{\beta}_j^{i,1}\right)}\hat{\beta}_j^{i,1} + \frac{SE\left(\hat{\beta}_j^{i,1}\right)}{\gamma + SE\left(\hat{\beta}_j^{i,1}\right)}\hat{\beta}_j^{i,\text{pool}}, \text{ for } j = 2, 3,$$

where $\gamma > 0$ is a tuning parameter.[4] We then re-estimate (II.1) by OLS but impose $\beta_j^i = \hat{\beta}_j^{i,2}$ for $j = 2, 3$. This approach allows countries to have distinct autoregressive coefficients and distinct reactions to GDP if the estimates in the first stage are precise (in the sense that the standard errors of the first stage coefficients are low). In contrast, if the initial country specific estimates are imprecise, our procedure stipulates that the reactions are governed relatively more by the pooled estimates. Note that we do not convexify the country specific intercept (β_0^i) or time trend (β_1^i).

In the second approach, we contrain the parameters β_2^i to some value taken from the literature and then re-estimate (II.1) to obtain estimates for the remaining parameters. We discuss these constrained values in greater detail below.

Under either approach, given the estimated (or constrained) coefficients, we use (II.1) to forecast G_t^i for periods after 2005. The out-of-sample forecasts use actual values of $\ln GDP_t^i$ but quasi-predicted values of $\hat{G}_t^i$.[5]

Table II.2a reports the statistical properties of the log difference between the actual time series and the forecast for each of the four fiscal variables: Government purchases (Gov), total government outlays (TO), total government revenue (TR) and the primary balance (PB). Subscript 1 indicates the baseline specification of the forecasting regression where we use the shrinkage

[4] The results presented below have

$$\gamma_j = \frac{\text{mean}_i\left(SE\left(\hat{\beta}_j^i\right)\right)}{3}.$$

This setting implies that a nation i with the average precision (given by its standard error) has a coefficient which places a weight of 0.75 on the pooled estimate. Note that for any fixed γ, the estimate $\hat{\beta}_j^{i,2}$ is a consistent estimator.

[5] Specifically, we form an iterative sequence of forecasts as follows. At the start of the forecast period (2006) we initialize G_{t-1}^i according to its actual value in 2005. For the next value however, we use the esitmated version of (II.1) to predict $\widehat{\ln G_t^i}$ given current X_t^i and $\widehat{\ln G_{t-1}^i}$. We repeat this procedure for the entire out-of-sample period using predicted values for $\ln G_t^i$ rather than actual values. Thus, $\widehat{\ln G_t^i}$ changes over time due only to realized changes in $\ln X_t^i$ and the time trend. See the appendix for additional details.

Table II.2a: Summary Statistics of Forecast Deviations: Government Finance Variables

	Gov_1	Gov_2	TO_1	TO_2	TR_1	TR_2	PB_1	PB_2
Average	−1.36	0.11	0.11	0.75	−2.82	−2.14	−2.26	−1.59
Std. dev.	13.70	16.57	13.42	18.95	11.09	13.60	4.17	4.48
				Correlation matrix				
Gov_1	1.00							
Gov_2	0.73	1.00						
TO_1	0.76	0.40	1.00					
TO_2	0.68	0.89	0.53	1.00				
TR_1	0.42	0.37	0.21	0.37	1.00			
TR_2	0.44	0.17	0.32	0.17	0.77	1.00		
PB_1	−0.19	−0.16	−0.33	−0.30	0.27	0.33	1.00	
PB_2	−0.18	−0.26	−0.27	−0.41	0.14	0.22	0.79	1.00

Notes: Table displays statistics of the log-difference between the actual time series and the forecast, averaged over 2010 - 2014, for government purchases, total outlays, total revenue and the primary balance. The first row displays the average of this difference across countries; the second row displays the standard deviation across countries. The remaining rows display the correlation across the various measures. For each government finance variable, the first forecast method uses the shrinkage estimator based on a time trend, contemporaneous GDP and its own lag; the second forecast method imposes the calibrated elasticity for contemporaneous GDP and re-estimates the remaining parameters (for the primary balance, the lag has been suppressed).

Table II.2b: Summary Statistics of Forecast Deviations: Economic Performance Variables

	GDP_1	GDP_2	Cons	Inv	Infl	NXGDP	XRT	$Growth_1$	$Growth_2$	Unempl
Average	-11.69	-20.08	-12.72	-31.11	1.22	4.54	2.60	0.99	0.98	9.86
Std. dev.	9.00	13.70	10.16	24.52	0.77	10.87	9.36	2.10	2.09	4.70
					Correlation matrix					
GDP_1	1.00									
GDP_2	0.50	1.00								
Cons	0.78	0.41	1.00							
Inv	0.87	0.54	0.79	1.00						
Infl	0.09	0.22	0.02	0.26	1.00					
NXGDP	0.46	-0.02	0.23	0.55	0.12	1.00				
XRT	0.35	0.26	0.17	0.20	-0.48	0.19	1.00			
$Growth_1$	0.57	-0.05	0.20	0.29	0.04	0.10	0.01	1.00		
$Growth_2$	0.57	-0.05	0.20	0.29	0.04	0.10	0.01	1.00	1.00	
Unempl	-0.63	-0.48	-0.59	-0.77	-0.41	-0.37	0.05	-0.19	-0.20	1.00

Notes: Table displays statistics of the log-difference between the actual time series and the forecast, averaged over 2010 - 2014, for GDP (using convergence, trend-hugging and combined estimators with a time trend and own lag), inflation, net exports over GDP, the nominal effective exchange rate (all using unit-root estimators), GDP growth (using convergence estimator and unit-root estimator) and unemployment (using unit-root estimator). The first row displays the average of this difference across countries; the second row displays the standard deviation across countries. The remaining rows display the correlation across the various measures.

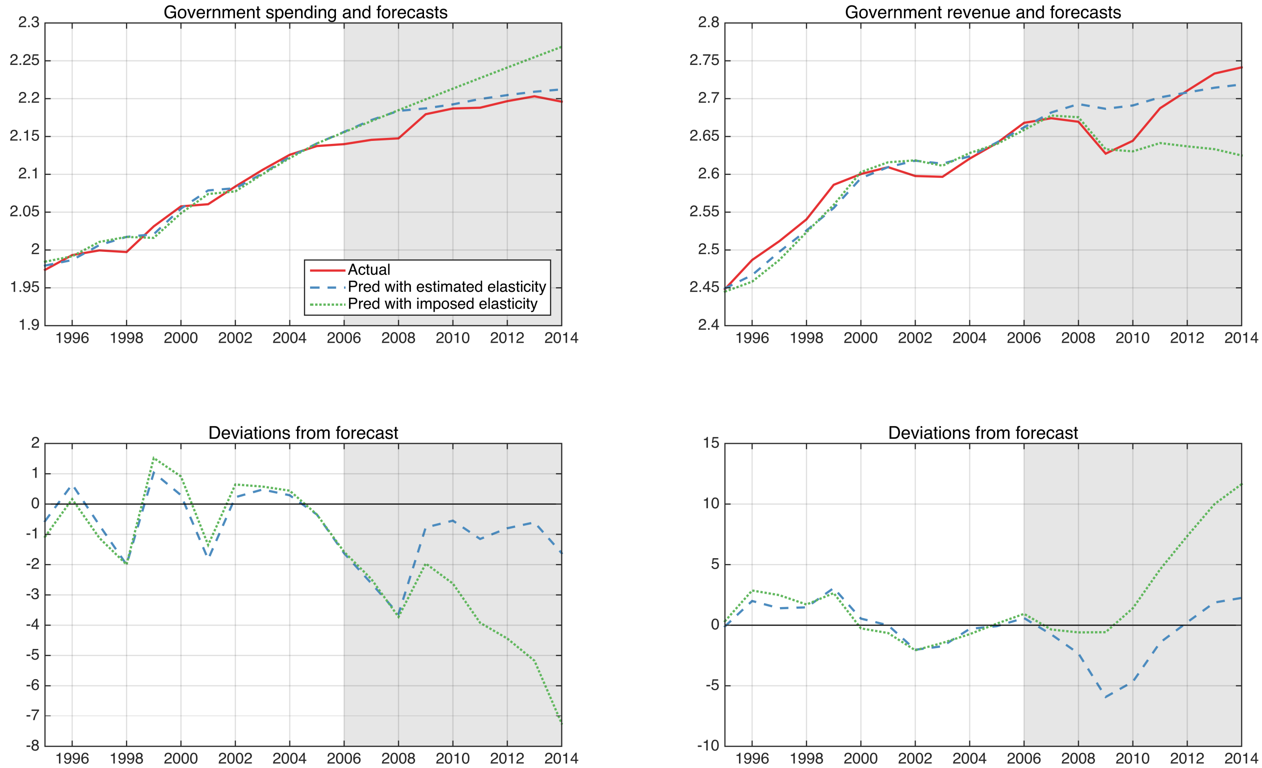


Figure II.2a: Measures of Austerity For France

Note: Upper panels display nominal government purchases and government revenue for France on a log scale, together with their predicted values using either estimated GDP elasticities or imposed GDP elasticities. Lower panels display the corresponding deviations of the actual series from their forecasts in log points.

estimator for β_2^i and β_3^i; subscript 2 indicates the alternate specification of (II.1) where we constrain the parameter β_2^i to values taken from the literature. The first row of the table – the mean of the deviation from forecast – indicates that the average of the four fiscal variables is small in the cross section. The standard deviations are large, reflecting the dispersion in policy responses across countries. The correlations in the bottom section of the table show that the forecasts are highly correlated across the two forecast specifications (ranging from 0.53 for TO_1 and TO_2 to 0.79 for PB_1 and PB_2).

Figures II.2a and II.2b show actual and forecast values of log government purchases and total revenues for two countries: France and Germany, respectively. During the 2010-14 period, France pursued a relatively austere path with actual government purchases falling short of the forecast. Tax revenues were also below forecast, especially towards the end of the sample period.

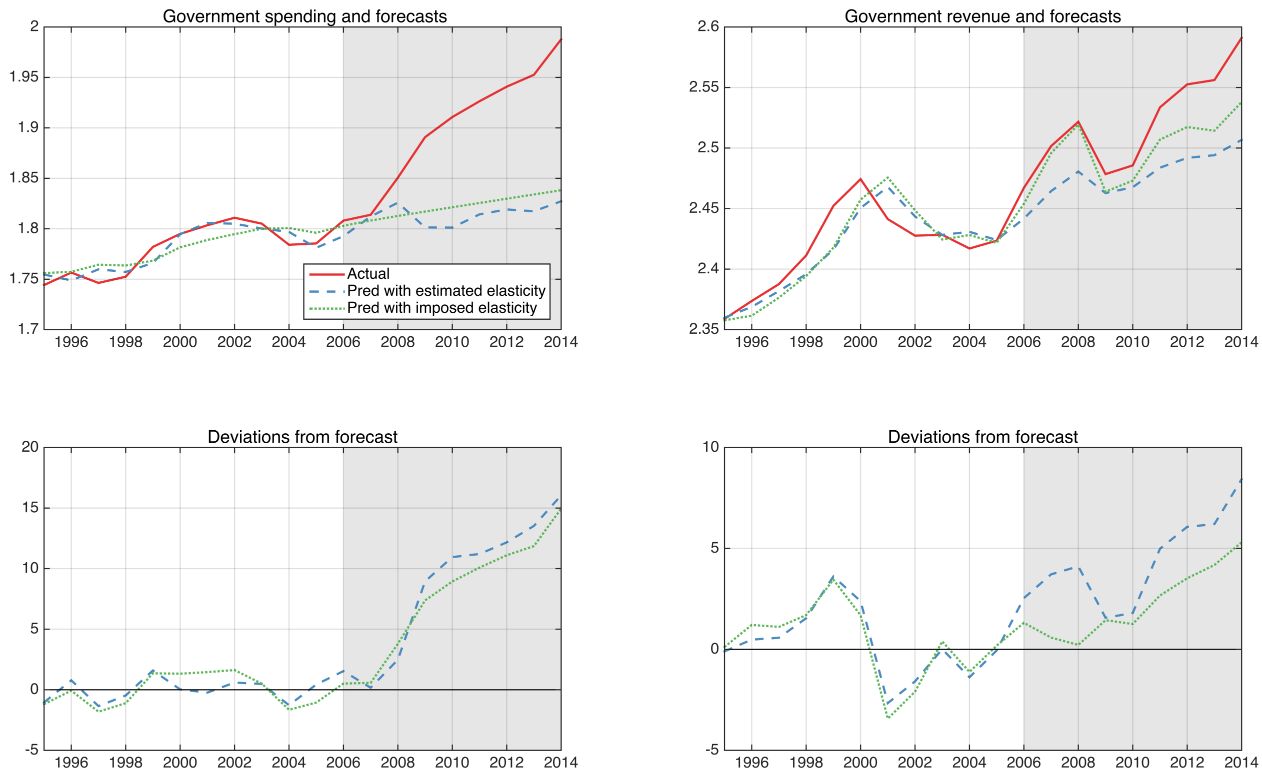


Figure II.2b: Measures of Austerity for Germany

Note: See Figure II.2a.

The forecast with the imposed revenue-to-GDP elasticity suggests 2010 as a starting point for revenue-driven fiscal consolidation. In Germany, on the other hand, austerity only took the form of somewhat higher-than-predicted tax revenues, whereas government purchases were clearly above trend. Whether such differences in austerity "shocks" can explain the cross-sectional patterns of economic outcomes in Europe is the focus of the next section.

2.3 Austerity and economic performance

Having constructed several alternative measures of austerity, we now estimate the relationship between austerity and economic performance. We report results for eight measures of economic activity: GDP, inflation, consumption, investment, net exports, the exchange rate, GDP growth and unemployment. We describe our procedure for forecasting these variables below.

Measuring economic performance For per capita real GDP, consumption and investment, we use forecasting specifications of the following form:

$$\ln Y_t^i = \beta_0^i + \beta_1^i t + \beta_2^i \ln Y_{t-1}^i + \varepsilon_t^i., \tag{II.2}$$

where Y is either GDP, consumption or investment. One of the difficulties in forecasting the future path of variables like GDP is that it is unclear how to detrend the series. Many countries in our sample had rapid rates of growth leading up to the crisis, a sharp fall during the crisis, and then a slower growth rate after the crisis. Applying the pre-crisis growth rate to the series produces massive output gaps in the post-crisis period. We adopt three alternative methods of detrending to address these problems.

First, following the method described for the austerity forecasts, we convexify the autoregressive parameter β_2^i with the pooled estimate across countries. We refer to this first forecast method as the "shrinkage" estimator. The second estimator imposes a condition on the trend based the pooled estimate β_2^{pool}. In particular, we require that the average deviations from the forecast are zero for each country. We refer to this second method as the "trend hugging" estimator. The third estimate appeals to basic growth theory and assumes that all countries are ultimately converging to a common growth rate. For this procedure, we estimate time-varying growth rates composed of two parts: a constant growth rate that reflects the average growth rate of Western European countries between 1993 and 2005, and a country-specific time-varying growth rate component that is a linear function of the log gap in real GDP per capita between the country and Western European aggregate.[6] We refer to this third method as the "convergence" estimator.

The statistical properties of the deviations from the forecast for log real GDP per capita are in the first three columns of Table II.2b. Specification 1 (denoted GDP_1 in the table) is the convergence estimator. Specification 2 is the trend hugging estimator. Specification 3 is the shrinkage estimator. Real GDP is below forecast for all three forecasting methods, ranging from -11.7 percent per year for specification 1 to -20.1 percent for specification 3. There is considerable heterogeneity across countries, reflected in the standard deviations in the second row. The forecast errors are positively correlated across specifications, particularly between the trend hugging estimator and the shrinkage estimator (specifications 2 and 3). For log consumption and log investment we follow a similar forecasting procedure. The table reports results only for the convergence estimator – our preferred specification. Consumption and investment, like GDP, are below forecast with considerable heterogeneity across countries.

Implicitly, our forecasts for GDP, consumption and investment all embody trend stationarity. Following the crisis, few countries experienced above average economic growth while many experienced below average growth during their recoveries. As a result, the trend stationary perspective embodied specification (II.2) produces large measures of the shortfall in GDP. Many researchers argue that GDP is best modelled as a unit root process in which shocks are essentially permanent.[7] To accommodate this view, we also produce forecasts for GDP growth. The growth rate forecasts take the view that the growth rates are stationary but the levels are in-

[6]The coefficient β_1^i in (II.2) is replaced with $\bar{\beta}_1 + \gamma \left(\ln GDP_{t-1}^{EU} - \ln GDP_{t-1}^{i} \right)$ where $\bar{\beta}_1$ is the average growth rate for Europe.

[7]See among others, Nelson and Plosser (1982), Rudebusch (1993), Kilian and Ohanian (2002), Campbell and Perron (1991) and Campbell and Mankiw (1987).

tegrated processes. But instead of assuming a pure random-walk specification for the growth rates, we use our growth rate estimates from our convergence estimator. This convergence estimator takes into account that growth rates in Central and Eastern European countries should be expected to slow down as their per capita GDP approaches Western European levels.

For the inflation rate, the unemployment rate, the effective exchange rate and the ratio of net exports to GDP, we impose a pure random-walk specification. To reduce the sensitivity to the last observation, for each country we take an average of the variable x_t^i for all quarters in the two years 2004 and 2005 as the last "observation."[8] That is, our forecast for these variables is simply

$$x_t^i = \frac{1}{8} \sum_{s \in 2004,2005} x_s^i + \varepsilon_t^i$$

for dates t after 2005:4. We use "core inflation" (all items less energy and food) as reported by Eurostat. For each country we use the nominal effective exchange rate which is an average of nominal exchange rates weighted according to the trade shares of each of country i's trading partners. On average (see the first row of Table II.2b, inflation, net exports to GDP and unemployment are all above forecast.

Austerity, GDP and inflation We estimate the relationship between countries' degree of austerity and their economic performance using a cross-sectional OLS regression:

$$\frac{1}{5} \sum_{t=2010}^{2014} \ln Y_{i,t} - \ln \widehat{Y}_{i,t} = \alpha_0 + \alpha_1 \frac{G_i}{GDP_i} \frac{1}{5} \sum_{t=2010}^{2014} \left(\ln G_{i,t} - \ln \widehat{G}_{i,t} \right) + \varepsilon_{i,t}. \tag{II.3}$$

Economic performance, the dependent variable, is measured as the log deviation of GDP, inflation etc. from its forecast, averaged over 2010 - 2014. Similarly, we average the forecast errors for our austerity measures over 2010 - 2014. We convert our austerity measures to the same units

[8] We have also experimented with specifications that build in persistence to these variables as

$$\ln x_t^i = \beta_0^i + \beta_1^i \ln x_{t-1}^i + \varepsilon_t^i.$$

However, for countries with adequate data, the estiamtes imply very low values for β_1^i. Because our focus is on performance several years into the future, the effects of this persistence are virtually zero.

as GDP by multiplying them by their share in GDP (averaged over 2000 - 2010). This allows us to directly interpret the coefficient α_1 as a multiplier (for $Y = GDP$) or the estimated effect of austerity in terms of percent changes in GDP.[9]

Tables II.3a and II.3b report the estimated coefficients $\hat{\alpha}_1$ for GDP and inflation. The top two rows show results for the shortfall in government purchases. For the entire sample of countries, the OLS regression coefficient for our measure of the GDP gap on austerity is -1.37 with a standard error of 0.49. Thus, a country with a shortfall in government purchases amounting to 1 percent of its GDP, sees a reduction in its GDP by 1.37 percent (relative to forecast). The table also reports separate results for subsamples of countries with fixed and floating exchange rates. We find evidence that the multiplier is larger for fixed exchange rate countries (1.79 vs. 0.94). The OLS estimate for inflation is -0.14 with a standard error of 0.10. So reducing government purchases by 1 percent of GDP is associated with a very mild reduction in inflation of 0.14 percentage points. Perhaps surprisingly, the effect is somewhat smaller (0.09 ppt.) in countries with floating exchange rates.

The other rows in Table II.3a show results for the shortfall in total outlays (purchases plus social benefits), total tax revenue and the primary balance. For total outlays, the results are similar to the shortfall in government purchases though the estimates for GDP are somewhat smaller overall (e.g., for the entire sample, the multiplier for outlays is -0.51 compared to the purchases multiplier, -1.37) and the estimates for inflation have changed sign for the overall sample and the two subsamples, but remain imprecisely estimated. The results for total revenues and the primary balance (revenue less outlays plus net interest payments) are counterintuitive. Taken at face value, the estimates for tax revenue seem to say that a one percent (of GDP) unforecasted increase in tax collections is associated with an *increase* in output of 0.72 percent for the entire sample. Similarly, the OLS estimate for the primary balance suggests that an unanticipated increases in the primary balance – either an increase in revenue or a decrease in

[9]This approach follows Hall (2009) and Barro and Redlick (2009). Ramey and Zubairy (2014) discusses the advantages of directly estimating the multiplier rather than backing it out from an estimated elasticity. Elasticities are likely to differ across countries if their fiscal sector vary in size. For instance, government purchases account for an average of 14 percent of GDP in Switzerland for 2000 - 2005, but 29 percent in Sweden.

Table II.3a: Austerity, GDP and Inflation: Using Estimated Elasticities

	All countries		Fixed XRT		Floating XRT	
	α_1	R^2	α_1	R^2	α_1	R^2
			Government Purchases (Shortfall)			
GDP	-1.37	0.22	-1.79	0.29	-0.94	0.19
	(0.49)		(0.65)		(0.73)	
Inflation	-0.14	0.07	-0.18	0.12	-0.09	0.03
	(0.10)		(0.12)		(0.19)	
			Total Outlays (Shortfall)			
GDP	-0.51	0.07	-0.56	0.09	-0.81	0.13
	(0.37)		(0.43)		(0.79)	
Inflation	0.07	0.03	0.08	0.06	0.02	0.00
	(0.07)		(0.07)		(0.20)	
			Total Revenue			
GDP	0.72	0.08	0.79	0.12	0.28	0.01
	(0.46)		(0.51)		(1.23)	
Inflation	-0.04	0.01	0.01	0.00	-0.31	0.16
	(0.09)		(0.09)		(0.27)	
			Primary Balance			
GDP	0.21	0.01	0.26	0.01	-0.47	0.04
	(0.41)		(0.51)		(0.90)	
Inflation	-0.00	0.00	-0.00	0.00	-0.04	0.01
	(0.08)		(0.08)		(0.22)	

Notes: Table displays the estimated coefficient on the government finance variable from regression (II.2) as well as its R^2. All government variables are forecasted using a time trend, GDP and an own lag. GDP is forecasted using the 'convergence' estimator. Inflation is forecasted using the unit root estimator. Reported standard errors in parentheses are (untreated) OLS errors.

Table II.3b: Austerity, GDP and Inflation: Using Imposed Elasticities

	All countries		Fixed XRT		Floating XRT	
	α_1	R^2	α_1	R^2	α_1	R^2
	Government Purchases (Shortfall, Elasticity = 0)					
GDP	-1.54	0.49	-1.59	0.47	-1.50	0.65
	(0.30)		(0.40)		(0.42)	
Inflation	-0.22	0.29	-0.20	0.29	-0.25	0.31
	(0.07)		(0.07)		(0.14)	
	Total Outlays (Elasticity = -0.05)					
GDP	-1.06	0.38	-1.09	0.36	-1.15	0.65
	(0.26)		(0.34)		(0.32)	
Inflation	-0.09	0.07	-0.09	0.09	-0.09	0.07
	(0.06)		(0.07)		(0.12)	
	Total Revenue (Elasticity = 1.05)					
GDP	-0.05	0.00	0.23	0.02	-1.74	0.44
	(0.37)		(0.41)		(0.75)	
Inflation	-0.02	0.00	0.01	0.00	-0.20	0.10
	(0.07)		(0.07)		(0.23)	
	Primary Balance (Elasticity = 0.20)					
GDP	-0.22	0.01	-0.53	0.05	-0.03	0.00
	(0.39)		(0.56)		(0.57)	
Inflation	0.02	0.00	-0.01	0.00	0.06	0.03
	(0.07)		(0.09)		(0.14)	

Notes: See Table II.3a. Government finance variables forecasted using imposed GDP elasticities.

expenditure – is associated with an increase in GDP.

We suspect that these counterintuitive results are driven by the estimates of the elasticity of the austerity variables to contemporaneous GDP. The main purpose of including contemporaneous GDP in the forecasting equations (II.1) was to include the typical predicted reactions of tax revenue or government purchases etc. to changes in GDP. There are mechanical relationships between tax collections and income that cause tax revenues to change with GDP and we want to exclude these effects from our measures of austerity. This is particularly important for tax revenue and social contributions. Our average estimated elasticity of tax revenue with respect to GDP is 0.57 – meaning that our forecasting regressions predict that tax revenue should rise by roughly half a percent for every one percent increase in GDP.[10] This is likely too low. Blanchard and Perotti (2002), Girouard and André (2005) and Giorno et al. (1995) report estimates of the tax elasticity that are much higher. Girouard and André (2005) report separate elasticities of capital income taxes, labor taxes, consumption taxes and social contributions. Taking a weighted average of their elasticities based on observed tax shares gives a predicted tax elasticity with respect to GDP of 1.05 – nearly twice the estimate from our forecast specification.

Using the estimates in Girouard and André (2005), we construct implied elasticities for all of our austerity measures. We then re-estimate equation (II.1) constraining the elasticities rather than estimating them. For government purchases shortfalls, the elasticity with respect to GDP (β_3^i in equation II.1) is set to 0. For shortfalls in total outlays, β_3^i is -0.05; for total tax revenue β_3^i is 1.05 and for the primary balance β_3^i is 0.20. Using these restricted forecasting equations, we again construct forecast errors for each austerity measure and repeat our analysis. The results are reported in Table II.3b.[11]

As before, the top two rows show results for the shortfall in government purchases. The GDP results are robust to whether the elasticity is calibrated or not. The estimated multiplier is -1.54 for the entire sample and no longer displays variation across exchange rate regimes.

[10] The full country-specific set of forecast estimates is available in the online appendix.

[11] The paths for government purchases and total revenue with a calibrated elasticity are shown for France and Germany in Figures II.2a and II.2b.

The estimates for inflation are slightly higher (-0.22 for the entire sample). The results for total outlays are somewhat higher than before and now there is a consistent negative impact on inflation. The greatest differences are associated with the tax measures and the primary balance. In the previous table, the estimates all had the "wrong" sign. With the calibrated tax elasticities, the estimates now suggest essentially no effect of taxes on GDP or inflation (though they are still estimated with substantial imprecision) and a consistent negative effect of the primary balance.

To summarize, we find consistent results that indicate that unanticipated reductions in government purchases are associated with large negative forecast errors in GDP and modest negative forecast errors in inflation. We find similar but smaller effects for total outlays. These results are robust to alternate forecast specifications. Results for tax revenue are not consistent across forecast specifications and are measured with substantial imprecision.

Government purchases shortfalls and economic performance Because the results for government purchases are the most robust relative to the other austerity measures, we provide more detail on the economic impacts of purchases austerity.[12] Table II.4 expands on the effects of government purchases austerity by including additional measures of economic performance. The table uses the forecast errors with an unconstrained GDP elasticity though the results for the calibrated GDP elasticity are quite similar.

According to the table, government purchases shortfalls are associated with large reductions in consumption and investment. The implied consumption multiplier is -1.52 and the investment multiplier is -3.01. These are large effects for government purchases shortfalls. The effect on investment is noteworthy because many models would predict a crowding out effect where reductions in government purchases would lead to increases in investment. That doesn't seem to be the case for our data. Both net exports and the trade-weighted exchange rate rise though the effect is statistically imprecise. Finally, unemployment rises by roughly 0.59 percentage points for government purchases reductions equal to one percent of GDP.

[12] Results for the other government finance variables are provided in the Appendix.

Table II.4: Austerity and Economic Performance

	Government Purchases (Shortfall)					
	All countries		Fixed XRT		Floating XRT	
	α_1	R^2	α_1	R^2	α_1	R^2
GDP	-1.37	0.22	-1.79	0.29	-0.94	0.19
	(0.49)		(0.65)		(0.73)	
Inflation	-0.14	0.07	-0.18	0.12	-0.09	0.03
	(0.10)		(0.12)		(0.19)	
Consumption	-1.52	0.22	-0.84	0.11	-2.43	0.41
	(0.55)		(0.58)		(1.10)	
Investment	-3.01	0.15	-4.09	0.22	-2.04	0.12
	(1.39)		(1.80)		(2.07)	
Net Exports	0.51	0.07	0.42	0.03	0.65	0.41
	(0.35)		(0.55)		(0.30)	
Exchange Rate	0.54	0.03	-0.14	0.00	1.43	0.15
	(0.57)		(0.49)		(1.31)	
GDP Growth	-0.26	0.16	-0.37	0.21	-0.14	0.21
	(0.11)		(0.17)		(0.10)	
Unemployment Rate	0.59	0.17	1.04	0.39	0.12	0.02
	(0.25)		(0.30)		(0.34)	

Notes: See Table II.3a. GDP, consumption and investment and GDP growth are forecasted using the 'convergence' estimator. Inflation, net exports, exchange rates and unemployment are forecasted using unit root. Exchange rate is the nominal effective exchange rate. Reported standard errors in parentheses are (untreated) OLS errors.

Fiscal spillovers We now analyze whether the effects of fiscal policy spill over to neighboring countries, following the approach taken in Auerbach and Gorodnichenko (2012). Specifically, we estimate the following regression:

$$\frac{1}{5}\sum_{t=2010}^{2014} \ln Y_{i,t} - \ln \widehat{Y}_{i,t} = \alpha_0 - \alpha_1 \times Gshock_{i,t} - \alpha_1^* \times Gshock_{i,t}^* + \varepsilon_{i,t}, \tag{II.4}$$

where $Gshock_{i,t}$ is country i's domestic austerity shock at time t:

$$Gshock_{i,t} = dom_i \frac{G_i}{GDP_i} \frac{1}{5} \sum_{t=2010}^{2014} \left(\ln G_{i,t} - \ln \widehat{G}_{i,t} \right)$$

and $Gshock_{i,t}^*$ is country i's spillover shock at time t:

$$Gshock_{i,t}^* = \sum_{j \neq i}^{N} imp_j^i \frac{G_j}{GDP_i} \frac{1}{5} \sum_{t=2010}^{2014} \left(\ln G_{j,t} - \ln \widehat{G}_{j,t} \right).$$

Country i's spillover shock $Gshock_i^*$ is the sum of all other countries' austerity shocks, expressed in terms of i's GDP and multiplied by a scaling factor, imp_j^i. This scaling factor is calculated as the share of country j's final demand that is satisfied by imports from country i. It therefore captures country i's exposure to changes in country j's final demand. By introducing this scaling factor, we implicitly assume that a country's GDP response to a €1 reduction in government purchases in another country scales with its exports to that country. The scaling factor therefore corrects for the observed heterogeneity in trade linkages across countries in our sample. In contrast to Auerbach and Gorodnichenko (2012), our scaling factor is calculated as a share of j's final demand, not j's government purchases. This captures the idea that changes in fiscal policy might not only directly translate into imports from other countries, but also indirectly through changes in consumption and investment. It also completely distributes the effects of fiscal austerity in j to all its trading partner and itself because $dom_j + \sum_{i \neq j}^{N} imp_j^i = 1$, where dom_j is country j's final demand that is satisfied by its domestic production.

The domestic austerity shock $Gshock_i$ applies this 'transmission-through-demand' idea to

Table II.5: AUSTERITY AND SPILLOVERS

	Government Purchases (Shortfall)								
	All countries			Fixed XRT			Floating XRT		
	α_1	α_1^*	R^2	α_1	α_1^*	R^2	α_1	α_1^*	R^2
GDP	-2.80	-23.72	0.41	-3.36	-20.96	0.52	-2.98	-52.65	0.38
	(0.69)	(9.33)		(0.84)	(9.18)		(1.55)	(36.91)	
Inflation	-0.30	-2.90	0.15	-0.34	-1.81	0.19	-0.62	-15.62	0.35
	(0.15)	(2.05)		(0.18)	(1.94)		(0.38)	(9.09)	
Consumption	-2.91	-20.91	0.33	-1.88	-19.19	0.36	-5.69	-66.38	0.50
	(0.83)	(11.23)		(0.76)	(8.31)		(2.45)	(58.17)	
Investment	-7.01	-81.45	0.41	-8.32	-71.35	0.54	-9.07	-202.02	0.53
	(1.88)	(25.34)		(2.16)	(23.58)		(3.68)	(87.58)	
Net Exports	0.34	-14.55	0.19	0.18	-15.66	0.18	1.11	3.85	0.41
	(0.53)	(7.20)		(0.79)	(8.62)		(0.71)	(16.94)	
Exchange Rate	1.01	3.65	0.04	0.12	13.34	0.15	-0.46	-93.06	0.39
	(0.92)	(12.36)		(0.71)	(7.73)		(2.67)	(63.58)	
GDP Growth	-0.58	-6.48	0.41	-0.72	-6.38	0.47	-0.41	-6.21	0.35
	(0.15)	(2.09)		(0.22)	(2.40)		(0.23)	(5.37)	
Unemployment Rate	1.00	1.37	0.20	1.63	-0.24	0.44	0.58	13.88	0.09
	(0.41)	(5.47)		(0.45)	(4.96)		(0.80)	(18.95)	

the domestic economy. In contrast to our baseline regression (II.3), we multiply the austerity shock by country i's share of final demand that is accounted for by domestic production, dom_i. This corrects for countries' trade openness and captures the idea that domestic fiscal shocks 'leak out' to other economies if a large share of final demand is satisfied by imports. Data on the domestic share, dom_i, and the import shares, imp_j^i, is taken from the OECD Trade in Value Added database, as explained in section .

Table II.5 display the results of regression (II.4) for a shortfall of government purchases. Adjusting domestic austerity shocks for the domestic share improves the fit of the regression and lowers relative standard errors relative to the benchmark results in Table II.4. The estimated coefficient $\hat{\alpha}$ is around -2.80 for GDP. This coefficient can be interpreted as a closed economy multiplier under the assumption that the effect of fiscal policy shocks on GDP perfectly scales with the domestic share dom.

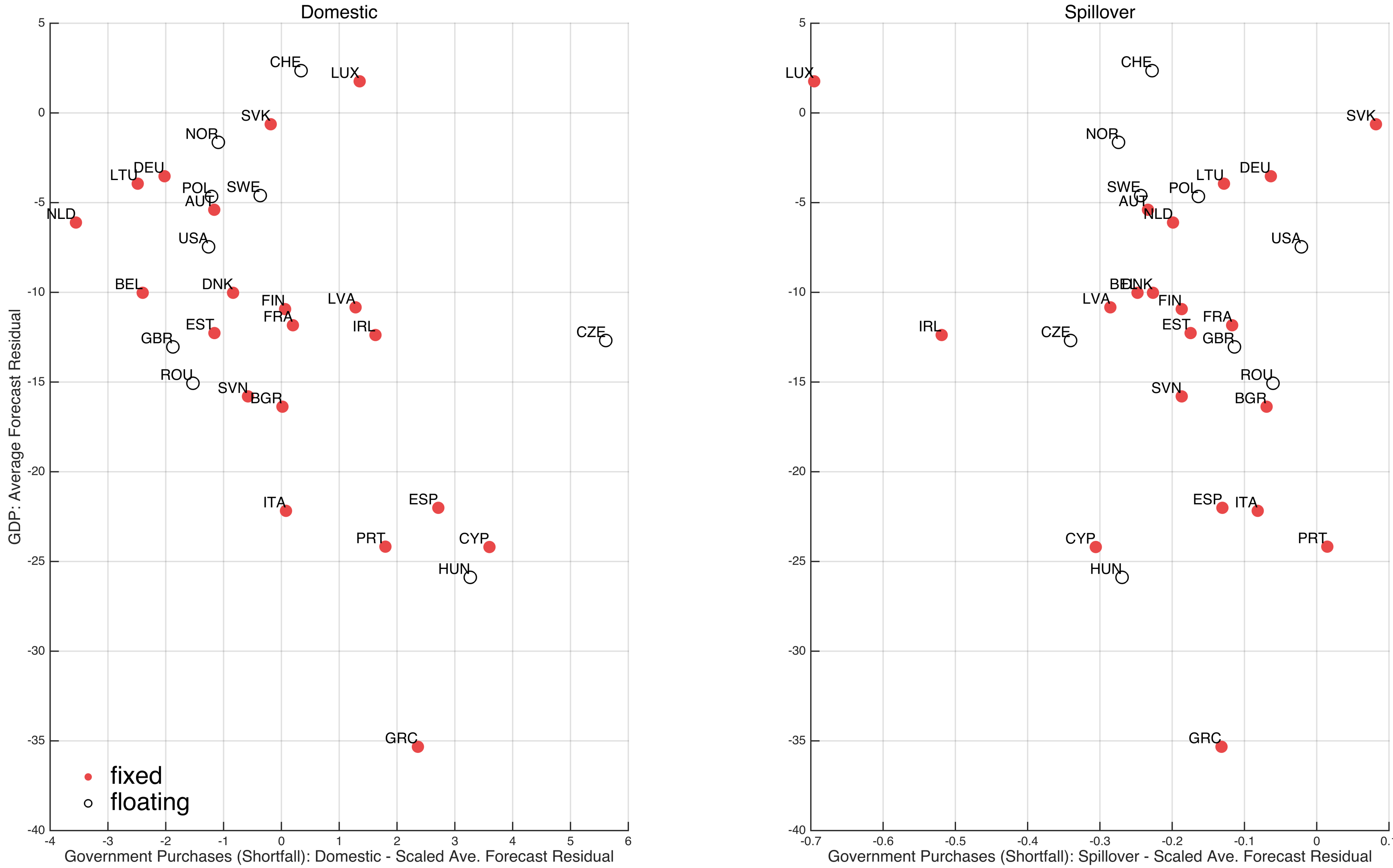


FIGURE II.3: GDP AND AUSTERITY IN DATA: DOMESTIC AND SPILLOVER EFFECT

Note: Figure displays a scatter plot of the average forecast residual of GDP over 2010 - 2014, in log points, versus the average forecast residual for the shortfall in government purchases, expressed in terms of a country's GDP and multiplied by a scaling factor. Left panel plots $Gshock$, the domestic austerity shock; right panel plots $Gshock^*$, the spillover shock. Countries are classified by their exchange rate regime (red: euro / pegged to euro; black: floating currency). See text for details on the forecast specification.

Figure II.3 illustrates the regression for GDP. The vertical axes of the two scatter plots display average forecast residual for GDP (the dependent variable in regression (II.4), in log points times 100. The horizontal axes display either the domestic austerity shock, $Gshock$, or the spillover shock, $Gshock^{*}$, in the same units as the GDP forecast residual. For example, 2 on the horizontal axis in the left panel is a *reduction* in government purchases, scaled by the domestic share of final demand, corresponding to 0.02 log points of GDP. As can be seen, variation in the spillover shocks is smaller than the variation in the domestic shock because export shares are somewhat lower than domestic shares. Also, exports are naturally diversified, so that positive and negative spillover effects from different export markets cancel each other out. Overall, spillover shocks in terms of government purchases were positive over the sample period, meaning that most countries faced increased government purchases in their export markets. This is mainly due to greater than predicted government purchases in large economies like Germany and the U.K.

The estimated results for the coefficient on the spillover shock in Table II.5 support the view that austerity in export markets dampens economic activity at home. The effects are qualitatively very similar to domestic austerity shocks, with the exception of net exports. Domestic austerity has no effect on net exports, whereas foreign austerity reduces net exports (but only in fixed exchange rate countries). This is in line with the idea that fiscal policy spills over to neighboring countries through trade. However, at face value, the estimates imply quantitatively implausible multipliers.[13]

3 Model

Here we present a multicountry business cycle model of the 29 countries in our data set. The model includes every country in the Eurozone (except for Malta) and is calibrated to roughly match both contemporaneous trade flows as well as recent long-run growth trajectories of cer-

[13] A simple back on the envelope calculation suggests that if all export markets equally raise government purchases by a total of €1, then the average country in our sample with an export-to-foreign-demand share of $\sum_{j\neq i}^{N} imp_j^i = 0.22$ sees its domestic GDP rise by more than €5. Our results cannot directly be compared to those reported in Auerbach and Gorodnichenko (2012). Among other things, we use a different scaling factor imp_j^i.

tain nations particularly the former Eastern Bloc countries. The model incorporates many features from modern monetary business cycle models (e.g., Smets and Wouters (2007), Christiano et al. (2005), international business cycles models (e.g., Backus et al. (1992), Backus et al. (1994), Chari et al. (2000), Heathcote and Perri (2002)), and financial accelerator models (e.g., Bernanke et al. (1999), Brave et al. (2012), Christiano et al. (2014)). The main ingredients of the model are (i) price and wage rigidity (ii) international trade in productive intermediate goods, (iii) a net worth chanel for business investment and (iv) government spending shocks, monetary policy shocks and spread shocks.

3.1 Households

The world economy is populated by $n = 1...N$ countries denoted by subscript i. The number of households in any country n is $\mathbb{N}_n$. The model is written in per capita terms. To convert any variable to a national total, we simply scale by the population. Thus if $X_{n,t}$ is per capita investment in country n at time t, total investment is simply $\mathbb{N}_n X_{n,t}$. In each period t the economy experienes one event s_t from a potentially infinite set of states. We denote by s^t the history of events up to and including date t. The probability at date 0 of any particular history s^t is given by $\pi(s^t)$.[14]

Every country has a representative household, a single type of intermediate goods producing firm and a single type of final goods producing firm. As in Heathcote and Perri (2002), intermediate goods are tradable across countries, but final goods are nontradable. The households own all of the domestic firms.

We assume that utility is separable in consumption and labor. At date 0, the expected discounted sum of future period utilities for a household in country n is given by

$$\sum_{t=0}^{\infty} \sum_{s^t} \pi(s^t)\beta^t \left[\frac{C_{n,t}^{1-\frac{1}{\sigma}}}{1-\frac{1}{\sigma}} - \kappa_n \frac{L_{n,t}^{1+\frac{1}{\eta}}}{1+\frac{1}{\eta}} \right]$$

[14]Unless confusion arises, we write $X_{n,t}$ instead of $X_n(s^t)$.

where $\beta < 1$ is the subjective time discount factor, σ is the intertemporal elasticity of substitution for consumption, η is the Frisch labor supply elasticity and κ_n is a country specific weight on the disutility of labor. Households choose consumption $C_{n,t} \geq 0$, next period's capital stock $K_{n,t+1} \geq 0$ and current investment $X_{n,t}$ for all s^t and for all $t \geq 0$ to maximize the expected discounted sum of future period utilities subject to a sequence of budget constraints. The allocation of labor $L_{n,t}$ is decided by monopolistically competitive labor supply unions (see below).

Households in each country own the capital stock $K_{n,t}$ of that country. They supply labor to the intermediate goods producing firms and capital to the entrepreneurs. In return, they earn nominal wages $W_{n,t}L_{n,t}$ and nominal payments for capital $\mu_{n,t}K_{n,t}$. Here $W_{n,t}$ is the nominal wage and $\mu_{n,t}$ is the nominal price of capital that prevail in country n at time t. Let $T_{n,t}$ denote nominal lump-sum taxes at time t. Finally, the household may also receive profits from domestic firms. Let $\Pi^f_{n,t}$ be nominal profits from intermediate good firms and Π^e be transfers from entrepreneurs paid to the household at time t.

Our specification of the payments associated with capital deserves some additional discussion. Rather than assuming that the households rent capital directly to firms, we assume that the households sell capital to entrepreneurs and then subsequently repurchase the undepreciated capital the following period. This assumption is convenient when we introduce financial market imperfections later.

In addition to direct factor incomes and transfer payments, the household may receive payments from both state-contingent and non-contingent bonds. Let $b_n(s^t, s_{t+1})$ be the quantity of state-contingent bonds purchased by the household in country n after history s^t. These bonds pay off in units of a reserve currency which we take to be U.S. dollars. Let $a\left(s^t, s_{t+1}\right)$ be the nominal price of one unit of the state-contingent bond which pays off in state s^{t+1}. Each country has non-contingent nominal bonds which can be traded. Let $S^j_{n,t}$ be the number of bonds denominated in country j's currency and held by the representative agent in country n. The gross nominal interest rate for country n's bonds is $1 + i_{n,t}$. The nominal exchange rate to convert country n's currency into the reserve currency is $E_{n,t}$.[15]

The nominal budget constraints for the representative household in country n are

$$P_{n,t}\left[C_{n,t}+X_{n,t}\right]+(1-\delta)\,\mu_{n,t}K_{n,t}+\sum_{j=1}^{N}\frac{E_{j,t}S_{n,t}^{j}}{E_{n,t}}+\mathbb{I}_{\text{comp}}\left[\sum_{s^{t+1}}\frac{a\left(s^{t},s_{t+1}\right)b_{n}(s^{t},s_{t+1})}{E_{n,t}}-\frac{b_{n}(s^{t-1},s_{t})}{E_{n,t}}\right]$$
$$=\mu_{n,t}K_{n,t+1}+W_{n,t}L_{n,t}+\Pi_{n,t}^{f}+\Pi_{n,t}^{e}+\sum_{j=1}^{N}\frac{E_{j,t}\left(1+i_{j,t-1}\right)S_{n,t-1}^{j}}{E_{n,t}}-T_{n,t}$$

and

$$K_{n,t+1}=K_{n,t}\left(1-\delta\right)+\left[1-f\left(\frac{X_{n,t}}{X_{n,t-1}}\right)\right]X_{n,t}$$

with $f(1)=f'(1)=0$ and $f''(1)\geq 0$. As in Christiano et al. (2005), the function $f\left(\cdot\right)$ features higher-order adjustment cost on investment if $f''\left(1\right)>0$.

The indicator variable $\mathbb{I}_{\text{comp}}$ takes the value 1 if markets are complete and 0 otherwise.[16] The first order conditions for an optimum are as follows.[17] The household's Euler equation for purchases of state contingent bonds $b_n(s^t,s_{t+1})$ requires

$$\frac{a\left(s^{t},s_{t+1}\right)}{E_{n,t}}\frac{1}{P_{n,t}}C_{n,t}^{-\frac{1}{\sigma}}=\beta\pi(s^{t+1}|s^{t})\frac{1}{E_{n,t+1}}\frac{1}{P_{n,t+1}}C_{n,t+1}^{-\frac{1}{\sigma}}\quad\forall s_{t+1}$$

where for convenience we are omitting the argument s^t for state-contingent variables when there is no ambiguity (i.e., we will write $C_{n,t}^{-\frac{1}{\sigma}}$ rather than $C_{n,t}\left(s^{t}\right)^{-\frac{1}{\sigma}}$, $P_{n,t}$ rather than $P_{n,t}\left(s^{t}\right)$, etc.). There are also Euler equations associated with the uncontingent nominal bonds $S_{n,t}^{j}$. These

[15] Technically, we assume that households also extend domestic loans to entrepreneurs, $B_{n,t}$, at a risky interest rate $(1+i_{n,t})F(\lambda_{n,t})e^{\epsilon_{n,t}^{F}}$. We later discuss these loans in more detail. We omit these loans for clarity reason in the budget contraint.

[16] Because models with incomplete markets often have non-stationary equilibria, we impose a small cost of holding claims on other countries. This cost implies that the equilibria is always stationary. For our purposes, we set the cost sufficiently low that its effect on the equilibrium is negligible.

[17] The reader will notice that the standard labor supply first order condition is "missing." The reason for this is that we appeal to market power on the part of labor suppliers (acting on behalf of the household) and thus, as in the typical sticky wage setting, wages are set above the market clearing level (i.e., workers are "off their labor supply curves").

require

$$\frac{C_{n,t}^{-\frac{1}{\sigma}}}{P_{n,t}}\frac{E_{j,t}}{E_{n,t}} = \beta\left(1+i_{j,t}\right)\sum_{s^{t+1}}\pi(s^{t+1}|s^{t})\left[\frac{E_{j,t+1}}{E_{n,t+1}}\frac{C_{n,t+1}^{-\frac{1}{\sigma}}}{P_{n,t+1}}\right] \text{ for all } j = 1...N.$$

Finally, the optimal choice for investment and capital requires

$$C_{n,t}^{-\frac{1}{\sigma}} = \mu_{n,t}\frac{C_{n,t}^{-\frac{1}{\sigma}}}{P_{n,t}} - \mu_{n,t}\frac{C_{n,t}^{-\frac{1}{\sigma}}}{P_{n,t}}\left[f_{n,t} + \frac{X_{n,t}}{X_{n,t-1}}f'_{n,t}\right] + \beta\sum_{s^{t+1}}\pi(s^{t+1}|s^{t})\left[\mu_{n,t}\frac{C_{n,t+1}^{-\frac{1}{\sigma}}}{P_{n,t+1}}f'_{n,t+1}\left(\frac{X_{n,t+1}}{X_{n,t}}\right)^{2}\right]$$

where the notation $f_{n,t}$ denotes the value of f evaluated at $X_{n,t}/X_{n,t-1}$.

Wage Setting

We follow the treatment by Erceg et al. (2000) and Christiano et al. (2005) by assuming that the household supplies labor to firms through unions that have some market power. Specifically, we assume that *effective* labor is a CES mix of different labor types. These labor types are aggregated by aggregation firms that then supply the labor aggregate to the firms at a nominal wage of $W_{n,t}$. Effective labor is given by

$$L_{n,t} = \left(\int_{0}^{1} l_{n,t}\left(z\right)^{\frac{\psi_l - 1}{\psi_l}} dz\right)^{\frac{\psi_l}{\psi_l - 1}}$$

where $L_{n,t}$ is the effective amount of labor supplied to the firms in country n at time t and $l_{n,t}\left(z\right)$ is the amount of type s labor supplied. The parameter $\psi_l > 1$ governs the degree to which different labor types are substitutable. The labor aggregating firm behaves competitively and supplies effective labor to the firms at the flow nominal wage $W_{n,t}$ but hires labor by type according to the type-specific nominal wages $w_{n,t}\left(z\right)$. Demand for each labor type is

$$l_{n,t}\left(z\right) = L_{n,t}\left(\frac{w_{n,t}\left(z\right)}{W_{n,t}}\right)^{-\psi_l} \qquad \text{(II.5)}$$

and the competitive aggregate nominal wage in country n at time t is

$$W_{n,t} = \left(\int_0^1 w_{n,t}\left(z\right)^{1-\psi_l} dz \right)^{\frac{1}{1-\psi_l}}.$$

Wages for each type of labor are set by monopolistically competitive worker-types. Given the elasticity of demand $-\psi_l$, workers desire a real wage $w_{n,t}\left(z\right)/P_{n,t}$ which is a constant markup over the marginal rate of substitution between consumption and leisure, $-U_{2,n,t+j}/U_{1,n,t+j}$ (i.e., the competitive wage). The desired markup is $\mu_w = \frac{\psi_l}{\psi_l - 1} > 1$.

As in Erceg et al. (2000), we model sticky wages with a Calvo mechanism. Let θ_w be the probability that a worker cannot reset his or her wage in a given period. Whenever possible, workers reset wages to maximize the utility of the representative household in country n. The marginal benefit of additional money at time $t+j$ is $C_{n,t+j}^{-\frac{1}{\sigma}}/P_{n,t+j}$ and the marginal disutility to the representative household from supplying additional labor is $\kappa_n L_{n,t+j}^{\frac{1}{\eta}}$. Workers take the demand curve (II.5) as given whenever they can choose a new reset wage. Denote the optimal reset wage in country n at time t as $w_{n,t}^*$. The optimal reset wage satisfies

$$w_{n,t}^* = \frac{\psi_l}{\psi_l - 1} \frac{-\sum_{j=0}^{\infty} \left(\theta_w \beta\right)^j \sum_{s^{t+j}} \pi(s^{t+j}|s^t) L_{n,t+j} W_{n,t+j}^{\psi_l} \kappa_n L_{n,t+j}^{\frac{1}{\eta}}}{\sum_{j=0}^{\infty} \left(\theta_w \beta\right)^j \sum_{s^{t+j}} \pi(s^{t+j}|s^t) L_{n,t+j} W_{n,t+j}^{\psi_l} \frac{C_{n,t+j}^{-\frac{1}{\sigma}}}{P_{n,t+j}}}. \tag{II.6}$$

Given (II.6), the nominal wage for effective labor evolves according to

$$W_{n,t} = \left[\theta_w \left(W_{n,t-1}\right)^{1-\psi_l} + \left(1 - \theta_w\right) \left(w_{n,t}^*\right)^{1-\psi_l} \right]^{\frac{1}{1-\psi_l}}.$$

3.2 Firms

There are three groups of productive firms in the model. First there are firms that produce the "final good." The final good is used for consumption, investment and government purchases within a country and cannot be traded across countries. The final good producers take intermediate goods as inputs. Second, intermediate goods firms produce country-specific goods which are used in production by the final goods firms. Unlike the final good, the intermediate goods are freely tradeable across countries. The intermediate goods firms themselves take sub-intermediate goods or varieties as inputs (the domestic producers of the tradeable intermediate in country n use only sub-intermediates produced in country n as inputs). The sub-intermediate goods are produced using capital and labor as inputs. Like the final good, neither capital nor labor can be moved across countries. Below we describe the production chain of these three groups of firms. We begin by describing the production of the intermediate goods which are traded across countries.

Tradeable Intermediate Goods

Each country produces a single (country-specific) type of tradeable intermediate good. The intermediate goods are used in the production of the final good which is ultimately the source of consumption and investment for each country. The intermediate goods are the only goods that can be traded between countries. Production of the intermediate good occurs in two stages. As we did with the supply of labor above, we employ a two-stage production process to allow us to use a Calvo price setting mechanism. In the first stage, monopolistically competitive domestic firms produce differentiated "sub-intermediate" goods which are used as inputs into the assembly of the tradeable intermediate good for country n. In the second stage, competitive intermediate goods firms produce the tradeable intermediate good from a CES combination of the sub-intermediates. These firms then sell the intermediate good on international markets at the nominal price $p_{n,t}$. We describe the two-stage process of production of the intermediate goods in reverse, starting with the second stage.

Second-Stage Producers The second stage producers assemble the tradeable intermediate good from the sub-intermediate varieties. The second stage firms are competitive in both the global market for intermediate goods and the market for subintermediate goods in their own country. The second-stage intermediate goods producers solve the following maximization problem

$$\max_{q_{n,t}(\xi)} \left\{ p_{n,t} Q_{n,t} - \int_0^1 \varphi_{n,t}(\xi)\, q_{n,t}(\xi)\, d\xi \right\}$$

subject to the CES production function

$$Q_{n,t} = \left[\int_0^1 q_{n,t}(\xi)^{\frac{\psi_q - 1}{\psi_q}}\, d\xi \right]^{\frac{\psi_q}{\psi_q - 1}}$$

where the parameter $\psi_q > 1$. Here $Q_{n,t}$ is the real quantity of country n's tradeable intermediate good produced at time t. The indexing variable ξ indexes the continuum of differentiated types of sub-intermediate producers (thus ξ is one of the sub-intermediate types). The parameter $\psi_q > 1$ governs the degree of substitutability across the sub-intermediate goods. The date t nominal price of each sub-intermediate good is $\varphi_{n,t}(\xi)$ and the quantity of each sub-intermediate is $q_{n,t}(\xi)$. It is straight-forward to show that the demand for each sub-intermediate has an iso-elastic form

$$q_{n,t}(\xi) = Q_{n,t} \left(\frac{\varphi_{n,t}(\xi)}{p_{n,t}} \right)^{-\psi_q}. \tag{II.7}$$

The competitive price of the intermediate $p_{n,t}$ is then a combination of the prices of the sub-intermediates. In particular,

$$p_{n,t} = \left[\int_0^1 \varphi_{n,t}(\xi)^{1-\psi_q}\, d\xi \right]^{\frac{1}{1-\psi_q}}. \tag{II.8}$$

First-Stage Producers The sub-intermediate goods $q_{n,t}(\xi)$ which are used to assemble the tradeable intermediate good $Q_{n,t}$ are produced in the first stage. The first-stage producers hire workers at the nominal wage $W_{n,t}$ and rent capital at the nominal rental price $R_{n,t}$ for use in production. Unlike the firms in the second stage, the first-stage, sub-intermediate goods firms are monopolistically competitive. They seek to maximize profits taking the demand curve for their product (II.7) as given. These firms each have access to a Cobb-Douglas production function

$$q_{n,t}(\xi) = Z_{n,t} \left[k_{n,t}(\xi) \right]^{\alpha} \left[l_{n,t}(\xi) \right]^{1-\alpha}.$$

Because the first-stage producers are monopolistically competitive, they typically charge a markup for their products. The desired price naturally depends on the demand curve (II.7). Each type of sub-intermediate good producer ξ freely chooses capital and labor each period but there is a chance that their nominal price $\varphi_{n,t}(\xi)$ is fixed to some exogenous level. In this case, the first-stage producers choose an input mix to minimize costs taking the date-t price $\varphi_{n,t}(\xi)$ as given. Cost minimization implies that

$$W_{n,t} = MC_{n,t}(1-\alpha) Z_{n,t} [k_{n,t}(\xi)]^{\alpha} [l_{n,t}(\xi)]^{-\alpha}$$

$$R_{n,t} = MC_{n,t} \alpha Z_{n,t} [k_{n,t}(\xi)]^{\alpha-1} [l_{n,t}(\xi)]^{1-\alpha}$$

where $MC_{n,t}$ is the marginal cost of production. The capital-to-labor ratios are constant for all of the sub-intermediate firms, in particular

$$\frac{k_{n,t}(\xi)}{l_{n,t}(\xi)} = \frac{\alpha}{1-\alpha} \frac{W_{n,t}}{R_{n,t}} = \frac{u_{n,t} K_{n,t}}{L_{n,t}}$$

This implies that (within any country n) the nominal marginal cost of production is constant across the sub-intermediate goods firms. Nominal marginal costs can be equivalently expressed in terms of the underlying nominal input prices $W_{n,t}$ and $R_{n,t}$

$$MC_{n,t} = \frac{W_{n,t}^{1-\alpha} R_{n,t}^{\alpha}}{Z_{n,t}} \left(\frac{1}{1-\alpha}\right)^{1-\alpha} \left(\frac{1}{\alpha}\right)^{\alpha}.$$

Pricing The nominal prices of the sub-intermediate goods are adjusted only infrequently according to the standard Calvo mechanism. We let $\varphi_{n,t}(\xi)$ denote the nominal price of sub-intermediate producer ξ that prevails at time t in country n. In particular, for any firm, there is a fixed probability θ_p that the firm cannot change its price that period. When a firm can reset its price it chooses an optimal reset price. Because the production functions have constant returns to scale, and because the firms are competitive in the input markets, all firms ξ that can reset their price at time t optimally choose the same reset price $\varphi^*_{n,t}(\xi) = \varphi^*_{n,t}$. The reset price is chosen to maximize the discounted value of profits. Firms act in the interest of the representative household in their country so they apply the household's stochastic discount factor to all future income streams. The maximization problem of a firm that can reset its price at date t is

$$\max_{\varphi^*_{n,t}} \sum_{j=0}^{\infty} (\theta_p \beta)^j \sum_{s^{t+j}} \pi(s^{t+j}|s^t) \frac{C_{n,t+j}^{-\frac{1}{\sigma}}}{P_{n,t+j}} \left(\varphi^*_{n,t} - MC_{n,t+j}\right) Q_{n,t+j} \left(\frac{\varphi^*_{n,t}}{p_{n,t+j}}\right)^{-\psi_q}$$

The solution to this optimization problem requires

$$\varphi^*_{n,t} = \frac{\psi_q}{\psi_q - 1} \frac{\sum_{j=0}^{\infty} (\theta_p \beta)^j \sum_{s^{t+j}} \pi(s^{t+j}|s^t) \frac{C_{n,t+j}^{-\frac{1}{\sigma}}}{P_{n,t+j}} \left(P_{n,t+j}\right)^{\psi_q - 1} MC_{n,t+j} Q_{n,t+j}}{\sum_{j=0}^{\infty} (\theta_p \beta)^j \sum_{s^{t+j}} \pi(s^{t+j}|s^t) \frac{C_{n,t+j}^{-\frac{1}{\sigma}}}{P_{n,t+j}} \left(P_{n,t+j}\right)^{\psi_q - 1} Q_{n,t+j}}.$$

Because the sub-intermediate goods firms adjust their prices infrequently, the nominal price of the tradeable intermediate goods are sticky. In particular, using (II.8), the nominal price of the tradeable intermediate good evolves according to

$$p_{n,t} = \left[\theta_p \left(p_{n,t-1}\right)^{1-\psi_q} + (1-\theta_p)\left(\varphi^*_{n,t}\right)^{1-\psi_q}\right]^{\frac{1}{1-\psi_q}}. \tag{II.9}$$

Our specification of price setting entails firms setting prices in their own currency. As a result, when exchange rates move, the implied import price moves automatically (there is complete pass-through). This is somewhat at odds with the data which suggests that many exporting firms fix prices in the currency of the country to which they are exporting. See Betts and Devereux (1996), Betts and Devereux (2000) and Devereux and Engel (2003) for a discussion of the differences between local currency pricing and domestic currency pricing. See Gopinath and Itskhoki (2011) and Burstein and Gopinath (2014b)for empirical evidence on the relationship between pass-through, price rigidity and exchange rate movements.

Non-Tradeable Final Goods

The final goods are assembled from a (country-specific) CES combination of tradeable intermediates produced by the various countries in the model. The final goods firms are competitive in both the global input markets (for the intermediate inputs) and the final goods market. The final goods producers solve the following maximization problem

$$\max_{y^j_{n,t}} \left\{ P_{n,t} Y_{n,t} - \sum_{j=1}^{N} \frac{E_{j,t}}{E_{n,t}} p_{j,t} y^j_{n,t} \right\}$$

subject to the CES production function

$$Y_{n,t} = \left(\sum_{j=1}^{N} \omega_{n,j}^{\frac{1}{\psi_y}} \left(y^j_{n,t} \right)^{\frac{\psi_y - 1}{\psi_y}} \right)^{\frac{\psi_y}{\psi_y - 1}} \tag{II.10}$$

Here, $y^j_{n,t}$ is the amount of country-j intermediate good used in production by country n at time t. The parameter ψ_y governs the degree of substitutability across the tradeable intermediate goods and we assume that $\omega_{n,j} \geq 0$ and $\sum_{j=1}^{N} \omega_{n,j} = 1$ for each country n. Notice that the shares $\omega_{n,j}$ are country-specific so each country produces a different mix of the various country-specific intermediate goods. Later, when we calibrate the model, we choose the $\omega_{n,j}$ parameters to match data on trade exposure.

Demand for country-specific intermediate goods is isoelastic

$$y^j_{n,t} = Y_{n,t} \omega_{n,j} \left[\frac{E_{j,t}}{E_{n,t}} \frac{p_{j,t}}{P_{n,t}} \right]^{-\psi_y}$$

The implied nominal price of the final good is

$$P_{n,t} = \left(\sum_{j=1}^{N} \omega_{n,j} \left[\frac{E_{j,t}}{E_{n,t}} p_{j,t} \right]^{1-\psi_y} \right)^{\frac{1}{1-\psi_y}}$$

Unlike the intermediate goods, the final good cannot be traded and must be used for either investment, consumption or government purchases in the period in which it is produced. Because the final goods firms have constant returns to scale production functions and behave competitively profits are zero in equilibrium.

3.3 The Supply of Capital and Financial Market Imperfections

The model incorporates a financial accelerator mechanism similar to Carlstrom and Fuerst (1997), Bernanke et al. (1999) and Christiano et al. (2014). Entrepreneurs buy capital goods from households using a mix of internal and external funds (borrowing). The entrepreneurs rent out the purchased capital to the first-stage sub-intermediate goods producers in their own country and then sell it back to the household the following period. The interest rate that entrepreneurs face for borrowed funds is a function of their financial leverage ratio. As a consequence, fluctuations in net worth cause changes in the effective rate of return on capital and thus directly affect real economic activity.[18]

Formally, at the end of period t, entrepreneurs purchase capital $K_{n,t+1}$ from the households at the nominal price $\mu_{n,t}$ per unit. Entrepreneurs finance the capital purchases with their own internal funds (net worth) and intermediated borrowing. Let end-of-period nominal net worth be $NW_{n,t}$. Then to purchase capital, the entrepreneur will have to borrow $B_{n,t} = \mu_{n,t}K_{n,t+1} - NW_{n,t}$ units of their own currency (entrepreneurs borrow money from the households in their country). Both $B_{n,t}$ and $NW_{n,t}$ are denominated in country n's currency. The nominal interest rate on business loans equals the nominal interest rate on safe bonds times an external finance premium $F(\lambda_{n,t})$, with $F(1) = 1, F'$ and $F'' > 0$. Here $\lambda_{n,t} = \frac{\mu_{n,t}K_{n,t+1}}{NW_{n,t}}$ is the leverage ratio.[19] The interest rate for securing next period capital is then $(1 + i_{n,t})\, F(\lambda_{n,t})e^{\epsilon^F_{n,t}}$, where $\epsilon^F_{n,t}$ is a shock to the interest rate spread. The function $F(\cdot)$ implies that entrepreneurs who are more highly levered pay a higher interest rate.

[18] See Brave et al. (2012) for the same approach. Christiano et al. (2014) microfound the dependence of the interest rate on the leverage ratio by introducing agency problems associated with financial intermediation.

[19] Technically we assume that for any $\lambda < 1$, $F(\lambda) = 1$ so there is no interest rate premium or discount for an entrepreneur who chooses to have positive net saving. Since the return on capital exceeds the safe rate in equilibrium, all entrepreneurs are net borrowers.

At the beginning of period $t+1$, entrepreneurs earn a utilization-adjusted rental price of capital $u_{n,t+1}R_{n,t+1}$ and then sell the undepreciated capital back to the households at the capital price $\mu_{n,t+1}$. Varying the utilization of capital requires $K_{n,t+1}a\left(u_{n,t+1}\right)$ units of the final good. Each period, a fraction $(1-\gamma_n)$ of the entrepreneurs' net worth is transferred to the households.[20]

Each period, entrepreneurs choose $K_{n,t+1}$ and utilization $u_{n,t+1}$ to maximize expected net worth $NW_{n,t+1}$. Net worth evolves over time according to

$$NW_{n,t+1} = \gamma_n \left\{ K_{n,t+1}\left[u_{n,t+1}R_{n,t+1} + \mu_{n,t+1}(1-\delta) - P_{t+1}a\left(u_{n,t+1}\right)\right] - (1+i_{n,t})F(\lambda_{n,t})e^{\epsilon^F_{n,t}}B_{n,t} \right\}.$$

We assume that the entrepreneurs can set utilization freely depending on the date t realization of the state. The utilization choice requires the first order condition

$$R_{n,t} = P_{n,t}a'\left(u_{n,t}\right).$$

We assume that the utilization cost function is $a\left(u\right) = \frac{\bar{R}}{P}\left[\exp\left\{h\left(u-1\right)\right\} - 1\right]\frac{1}{h}$, where the curvature parameter h governs how costly it is to increase or decrease utilization from its steady state value of $u=1$ (see Christiano et al., 2005). Note that in steady state $a\left(u\right)=0$.

The first order condition for the choice of $K_{n,t+1}$ requires

$$(1+i_{n,t})F(\lambda_{n,t})e^{\epsilon^F_{n,t}} = \frac{\sum_{s^{t+1}}\pi(s^{t+1}|s_t)\left[u_{n,t+1}R_{n,t+1} + \mu_{n,t+1}\left(1-\delta\right) - P_{t+1}a\left(u_{n,t+1}\right)\right)]}{\mu_{n,t}}.$$

As is standard in financial accelerator models, the external finance premium $F(\lambda_{n,t})$ drives a wedge between the nominal interest rate on bonds and the expected nominal return on capital.[21] Notice that if $F\left(\lambda_{n,t}\right)=1$ then we obtain the standard efficient outcome in which the market price of capital is the discounted stream of rental prices.

[20] We set $\gamma_n = \frac{\beta}{F_n}$ so that net worth is constant in a stationary equilibrium.

[21] Our specification technically requires that the banks do not directly observe individual leverage ratios but instead observe only country-wide leverage when they set interest rates.

3.4 Government Policy

The model includes both fiscal and monetary policy variables. We assume that government spending is exogenous and financed by lump sum taxes on the representative households. Government spending in country n is governed by a simple auto-regressive process

$$G_{n,t} = (1 - \rho_G)\, G_n + \rho_G G_{n,t-1} + \varepsilon^G_{n,t}.$$

We choose the parameter G_n to match observe ratio's of government spending to GDP for each country.

Monetary policy is conducted through a Taylor Rule which stipulates that in each country, a monetary authority conducts open market operations in its own currency to target the nominal interest rate. The Taylor Rule we use has the form

$$i_{n,t} = \bar{\imath}_n + (1 - \phi_i)\, (\phi_{GDP} GDP_{n,t} + \phi_\pi \pi_{n,t}) + \phi_i i_{n,t-1} + \varepsilon^i_{n,t} \tag{II.11}$$

For simplicity we assume that the reaction parameters ϕ_{GDP}, ϕ_π and ϕ_i are common across countries. In all of our numerical exercises, we require that $\frac{\phi_\pi}{1-\phi_i} > 1$ for local determinacy of the equilibrium (see e.g., Woodford and Walsh (2005)).

Countries in a currency union have a fixed nominal exchange rate for every country in the union. Because *currency* is freely mobile across countries, nominal interest rates for countries in a currency union must also be equal. As a consequence, individual nations in a currency union cannot have independent monetary policies. Instead, we assume that monetary policy for the countries within the union are set by a single monetary authority (the ECB in our case) that has a Taylor Rule similar to (II.11) with the exception that it reacts to the weighted average of innovations in GDP and inflation for the countries in the union. For our purposes, the currency union consists only of the countries in the Eurozone and the weights are proportional to GDP relative to the total GDP in the Eurozone.

3.5 Aggregation and Market Clearing

For each country n, aggregate production of the tradeable intermediate goods is (up to a first-order approximation[22]) given by

$$Q_{n,t} = Z_{n,t} \left(u_{n,t} K_{n,t} \right)^{\alpha} L_{n,t}^{1-\alpha}.$$

Final goods production is given by (II.10) and, since the final good is non-tradeable, the market clearing condition for the final good is

$$Y_{n,t} = C_{n,t} + X_{n,t} + G_{n,t} + a \left(u_{n,t} \right) K_{n,t}.$$

The market clearing for the intermediate goods produced by country n is

$$Q_{n,t} = \sum_{j=1}^{N} \frac{\mathbb{N}_j}{\mathbb{N}_n} y_{j,t}^{n}.$$

Finally, the bond market clearing conditions require

$$\sum_{n=1}^{N} \mathbb{N}_n S_{n,t}^{j} = \sum_{n=1}^{N} \mathbb{N}_n b_n(s^t, s_{t+1}) = 0 \qquad \forall j.$$

The definition of net exports. Since no final goods are traded, net exports are comprised entirely of intermediate goods. For each country n, define nominal net exports as

$$NX_{n,t} = p_{n,t} Q_{n,t} - \sum_{j=1}^{n} \frac{E_{j,t}}{E_{n,t}} p_{j,t} y_{n,t}^{j} = p_{n,t} Q_{n,t} - P_{n,t} Y_{n,t}$$

[22] As is well known in the sticky price literature, actual output includes losses associated with equilibrium price dispersion. In a neighborhood of the steady state, these losses are zero to a first order approximation. Since our solution technique is only accurate to first order, these terms drop out.

where the second equality follows from the zero profit condition for the final goods producers. We can use this expression to write nominal GDP as

$$NGDP_{n,t} = p_{n,t}Q_{n,t} = NX_{n,t} + P_{n,t}\left[C_{n,t} + X_{n,t} + G_{n,t}\right]$$

Note, since the equilibrium price level in the steady state is $P = 1$, real GDP is $RGDP_{n,t} = Q_{n,t}$ (this is the real GDP calculation associated with a fixed price deflator in which the base year prices are chosen as corresponding to the steady state).

3.6 Steady state

We express each variable's stationary equilibrium in terms of the final good, Y_n.[23] We directly calibrate a certain number of steady-state variables to their empirical counterpart. Those are the shares of government purchases, G_n, net exports, NX_n, and the relative country sizes, $\frac{\mathbb{N}_n Y_n}{\mathbb{N}_m Y_m}$. We now derive the shares of the remaining variables, C_n and X_n, and later show that these non-targeted shares implied by our model match their empirical counterparts quite closely.

Steady-state inflation is zero, so that nominal prices are constant. We normalize the price level P_n to 1.

We first solve for the steady-state rental price of capital. Combining the Euler equation for capital with the Euler equation for domestic bonds gives an expression for the rental price of capital in terms of parameters

$$R_n = \frac{F(\lambda_n)}{\beta} - (1-\delta).$$

The rental price of capital is the marginal product of capital, reduced by the inverse of the markup $\frac{\psi_q - 1}{\psi_q}$.

$$R_n = \frac{\psi_q - 1}{\psi_q} p_n \alpha Z_n \left(\frac{K_n}{L_n}\right)^{1-\alpha}.$$

[23]For any variable $X_{n,t}$, X_n denotes the corresponding steady-state value.

We adjust the technology level Z_n so that all intermediate goods prices, expressed in the reserve currency, are 1 in steady state: $p_n E_n = 1$. Then, using the price index formula for the final good gives

$$1 = \left(\sum_{j=1}^{N} \omega_{n,j} \left[\frac{E_j}{E_n} p_j \right]^{1-\psi_y} \right)^{\frac{1}{1-\psi_y}} .$$

Since the prices of all intermediate goods are $p_j E_j = 1$, one can easily verify that $E_n = 1$ solves this equation, that means the real exchange rate is unity. It follows from the demand equation for intermediate goods that $\omega_{n,j}$ is country n's import share of country j's good, measured in terms of the privately-produced good Y_n:

$$\omega_{n,j} = \frac{y_n^j}{Y_n}.$$

Later, we use data on imports to calibrate $\omega_{n,j}$. The implied net export share can be expressed in terms of country sizes and the import preference parameters. Inserting the market clearing condition for Q_n into the definition of net exports, $NX_n = Q_n - Y_n$, we have

$$\begin{aligned} \frac{NX_n}{Y_n} &= \left(\sum_{j=1}^{N} \frac{\mathbb{N}_j}{\mathbb{N}_n} y_j^n \right) - 1 \\ &= \left(\sum_{j=1}^{N} \frac{\mathbb{N}_j Y_j}{\mathbb{N}_n Y_n} \omega_{j,n} \right) - 1. \end{aligned}$$

Starting from the definition of net exports, $NX_n = Q_n - Y_n$, and inserting the marginal product of capital equation for Q_n, that is $Q_n = \frac{\psi_q}{\psi_q - 1} \frac{R_n}{\alpha} K_n$ with $\delta K_n = X_n$ gives

$$\begin{aligned} \frac{\psi_q}{\psi_q - 1} \frac{R_n}{\alpha\delta} X_n &= Y_n + NX_n \\ \frac{X_n}{Y_n} &= \frac{\alpha\delta}{\frac{\psi_q}{\psi_q - 1} R_n} \left(1 + \frac{NX_n}{Y_n} \right). \end{aligned}$$

Using the market clearing condition $Y_n = C_n + X_n + G_n$ gives the consumption share as a residual:

$$\frac{C_n}{Y_n} = 1 - \frac{X_n}{Y_n} - \frac{G_n}{Y_n}.$$

3.7 Calibration

Preferences We set the subjective time discount factor β to imply a long run real annual interest rate of four percent. We set the intertemporal elasticity of substitution σ to 0.50 and the Frisch elasticity of labor supply η to 1. These values are comparable to findings in the microeconomic literature on preference parameters (e.g. Barsky et al., 1997)).

Trade and Country Size The preference parameters ω_n^j are calibrated to the share of imports y_n^j in the production of the final good, Y_n, in the data. Standard import data cannot be used for this purpose because it is measured in gross terms, wheras our model requires data in value added terms. We therefore use data from the OECD dataset on trade in value added (TiVA). The dataset is derived from input-output tables, which themselves are based on national account data. The definition of imports and exports in TiVA correspond to those used in national account data and therefore captures both trade in goods and services. The data series FD_VA has information on the value added content (in US dollars) of final demand by source country for all country pairs in our data sample. We directly use these values for y_n^j and the implied final demand value for Y_n to calculate ω_n^j. TiVA also has data for a 'rest of the world' aggregate. We lump together that data and data for countries that are not in our sample to construct the preference parameters ω_{RoW}^j for the rest of the world in our sample. TiVA is available for 1995, 2000, 2005, and 2008 through 2011. We take an average of 2005 and 2010 to calibrate ω_n^j.

The trade elasticity ψ_y is set to 1.5. This is comparable to calibrations used in international business cycle models with trade. In their original paper, Heathcote and Perri (2002) estimated $\psi_y = 0.90$. Backus et al. (1994) set the trade elasticity to 1.5. Using firm-level data, Cravino

(2014) and Proebsting (2015) find elasticities close to 1.5.[24].

Country sizes are expressed in final demand, $\mathbb{N}_n Y_n$. We choose the relative country sizes to match relative final demand observed in the TiVA tables, using an average of 2005 and 2010.

Technology The capital share parameter α is set to 0.38, as in Trabandt and Uhlig (2011) who match data for 14 European countries and the US. The quarterly depreciation rate is set to 1.7% to match the share of private investment in final demand, X_n/Y_n, whose average value was 19.7% across all countries in our sample for the years 2000 - 2010.

The form of the investment adjustment cost $f\left(.\right)$ implies a simple relationship between investment growth and Tobin's Q. In particular, if $v_{n,t}$ is the Lagrange multiplier in the capital accumulation constraint then Tobin's Q can be defined as $\mathbb{Q}_{n,t} = v_{n,t}/C_{n,t}^{-\frac{1}{\sigma}}$. It is straightforward to show that the change in investment growth over time obeys the equation

$$\left[\tilde{X}_{n,t} - \tilde{X}_{n,t-1}\right] = \frac{1}{\kappa}\tilde{\mathbb{Q}}_{n,t} + \beta\left[\tilde{X}_{n,t+1} - \tilde{X}_{n,t}\right]$$

where $\tilde{X}$ denotes the percent deviation from X from its steady state value. Thus the parameter κ is similar to a traditional inverse Q-elasticity. We adopt the value $\kappa = 2.48$ from Christiano et al. (2005) which implies that a one percent increase in Q causes investment to increase by roughly 0.4 percent.

For the utilization cost function $a\left(u\right) = \frac{\bar{R}}{P}\left[\exp\left\{h\left(u-1\right)\right\} - 1\right]\frac{1}{h}$, the elasticity of utilization with respect to the real rental price of capital is governed by the parameter $h = \frac{a''(1)}{a'(1)}$. We follow Del Negro et al. (2013) by setting $h = 0.286$. This implies that a one percent increase in the real rental price $R_{n,t}/P_{n,t}$ causes an increase in the capital utilization rate of 0.286 percent.

Price and Wage Rigidity We calibrate the Calvo price and wage setting hazards to roughly match observed frequencies of price adjustment in the micro data. For price rigidity, Nakamura and Steinsson (2008) report that prices change roughly once every 8 to 11 months; Klenow and

[24]The literature on international trade outside of business cycle analysis typically adopts higher elasticities. For instance Broda et al. (2006) find a long-run trade elasticity of 6.8.

Kryvtsov (2008) report that prices change roughly once every 4 to 7 months. Evidence on price adjustment in Europe suggests somewhat slower adjustment. Alvarez et al. (2006) find that the average duration of prices is 13 months (for a quarterly model this corresponds to $\theta_p = 0.77$). The evidence on wage rigidity is somewhat more sparse. Perhaps the best study is Barattieri et al. (2014) who use a careful analysis of SIPP data to conclude that wages change on average once every 12 months (which corresponds to $\theta_w = 0.75$).[25] Our baseline calibration takes $\theta_p = 0.80$ and $\theta_w = 0.80$. These are somewhat higher than the empirical findings for U.S. price and wage adjustment. Our main reason for adopting this calibration is to match the data indicating slightly more sluggish price adjustment in European countries compared to the U.S.[26]

Financial Market Imperfections The steady state external finance premiums, $F_n(\lambda_s s)$, are calculated as the average spread between lending rates (to non-financial corporations) and central bank interest rates. For every country, we calculate an average across 2000 (or earliest available) through 2010. The data source for the spread data is the ECB for euro area countries, and the Global Financial Database and national central banks for the remaining countries. See the appendix for more details on the data sources.

For the two remaining parameters we adopt the calibration rom Brave et al. (2012). The elasticity of the external finance premium with respect to leverage F_ϵ is 0.20 and the quarterly persistence of the shocks to the external finance premium is set to 0.99.

Fiscal and Monetary policy We set the steady state ratio of government purchases to GDP to match the average ratio in data provided by the OECD and Eurostat for 2000 to 2010. Our benchmark calibration is summarized in Table II.6. The persistence of the government purchase shock is set to 0.93 as in Del Negro et al. (2013). We choose our Taylor rule parameters to be $\phi_\pi = 1.5$, $\phi_{GDP} = 0.5$ and $\rho_i = 0.75$.

[25] If there are implicit wage contracts then the average frequency of wage adjustment may not be the relevant metric to guage how rapidly wage payments respond to economic conditions. See Basu and House (2016) for a review of the literature on wage adjustment in macroeconomic models.

[26] For purposes of comparison, Christiano et al. (2005) have $\theta_p = 0.6$ and $\theta_w = 0.64$, Del Negro et al. (2013) have $\theta_p = 0.6$ and $\theta_w = 0.64$ and Brave et al. (2012) have $\theta_p = 0.97$ and $\theta_w = 0.93$.

Table II.6: Calibration

Description	Parameter	Value	Source
Preferences			
Discount factor (quarterly)	β	0.99	Standard value
Coefficient of relative risk aversion	$\frac{1}{\sigma}$	2	Standard value
Frisch elasticity of labor supply	η	1	Barsky et al. (1997)
Trade and Country Size			
Trade preference weights	ω_n^j	x	OECD Trade in Value Added Dataset
Trade demand elasticity	ψ_y	1.5	e.g. Backus et al. (1994), Cravino (2014), Proebsting (2015)
Country size	$\mathbb{N}_n Y_n$	x	OECD Input-Output Tables
Technology			
Capital share	α	0.38	Trabandt and Uhlig (2011)
Depreciation (quarterly)	δ	0.022	Average private investment share, $X/Y = 0.197$, 2000 - 2010
Utilization cost	a''	0.286	Del Negro et al. (2013)
Investment adjustment cost	f''	2.48	Christiano et al. (2005)
Elasticity of substitution between varieties	ψ_q	10	Standard value
Price and Wage Rigidity			
Sticky price probability	θ_p	0.80	Alvarez et al. (2006)
Sticky wage probability	θ_w	0.80	Barattieri et al. (2014)
Financial Market Imperfections			
SS External finance premium	$F_n(\lambda_{ss})$	x	ECB, Global Financial Database and national sources
Elasitcity external finance premium	F_ϵ	0.20	Brave et al. (2012)
Persistence spread shock	ρ_F	0.99	Brave et al. (2012)
Fiscal and Monetary Policy			
Gov't purchases over final demand	$\frac{G_n}{Y_n}$	x	OECD and Eurostat
Persistence government spending shock	ρ_G	0.93	Del Negro et al. (2013)
Taylor rule persistence	ϕ_i	0.75	
Taylor rule GDP coefficient	ϕ_{GDP}	0.5	
Taylor rule inflation coefficient	ϕ_π	0.5	

Notes: Values marked with x are country- or country-pair specific.

4 Model and Data Comparison

We can now simulate the calibrated model's reaction to austerity shocks to compare the model's reaction to the observed patterns in the data. Our approach is to treat the austerity forecast deviations calculated in Section 2 as structural shocks. To incorporate these shocks, we first modify the forecast deviations to quarterly data (the data in Table II.4 was annual because we only have quarterly data for a short time period). To construct quarterly forecasts we use forecasting equation (II.1) which includes a time trend, as well as lagged government spending and contemporaneous GDP. We impose the same estimated coefficients from the annual forecasting equation used to create Table II.4 but we adjust the parameters for quarterly frequencies (e.g., the time variable proceeds in quarters of a year rather than integers). The shock is then the log difference between actual quarterly government spending and forecast government spending. We ignore tax shocks and shocks to the primary balance since these shocks appear to exert only a minor influence on the system.

In addition to the austerity shocks, we also include shocks to monetary policy and shocks to financial markets. Including other shocks is important because it is likely that some of the observed differences in economic performance can be traced to shocks other than austerity. We describe these additional shocks below.

4.1 Forcing Variables

In addition to the austerity shocks, we will include shocks to monetary policy and shocks to the financial sector. Here we briefly describe how these shocks are constructed.

Monetary Policy Shocks To estimate monetary policy shocks we proceed as follows. We begin by estimating a generalized Taylor rule of the form suggested by Clarida et al. (1997).[27]

$$i_t = \rho_i i_{t-1} + (1-\rho_i)\left[\pi_t + r + \phi_\pi(\pi_t - \pi^*) + \phi_{GDP}\%GDP_t\right] + \varepsilon_t^i$$

where i_t is the nominal interest rate, r is the long-run interest rate, π_t is inflation, π^* is the inflation target, $\%GDP_t$ are percent deviations of real GDP from its trend (i.e., the output gap), and ε_t^i is a structural shock. Inflation is measured using the GDP deflator. The interest rate and the inflation rate are measured in annual percent. We estimate this rule by first imposing the original estimate of $\rho = 0.79$ by Clarida et al. (1997) and then estimating ϕ_π and ϕ_{GDP} for the U.S. over the period 1980.1 - 2005.4. This estimation implicitly assumes that the U.S. has been adhering to a fairly stable monetary rule since the early 1980's.

We then impose the estimated coefficients ϕ_π, ϕ_{GDP} and the constrained coefficient ρ for each of the countries in Europe that have an independent monetary policy. We do not estimate separate Taylor rules for each central bank primarily because of data limitations. For the Eurozone, we assume that the ECB reacts to the weighted average of inflation and output over all countries in the Euro. With these coefficients we then estimate country-specific intercepts (corresponding to the parameters $r - \pi$ in the Taylor rule). We can then recover the monetary policy shocks for each country n as $\hat{\varepsilon}_{n,t}^i = i_{n,t} - \hat{\imath}_{n,t}$.

Financial Shocks We take our measure of financial shocks from data on spreads between lending rates and central bank interest rates. For the U.S., data on lending rates comes from the Federal Reserve Survey of Terms of Business Lending. For European countries, we use a dataset provided by the ECB, which we supplement with data from national central banks and the Global Financial Database.

[27] The original rule analyzed by Clarida et al. (1997) depends on expected inflation and the expected output gap instead of contemporaneous inflation and output gap.

Table II.7: Comparison of Model and Data: Benchmark Calibration

	Data			Benchmark		
	All	Fix	Float	All	Fix	Float
GDP	-1.37	-1.76	-0.92	-0.58	-0.55	-0.63
	(0.48)	(0.62)	(0.74)			
Inflation	-0.14	-0.17	-0.09	0.00	-0.04	0.04
	(0.10)	(0.11)	(0.19)			
Consumption	-1.48	-0.83	-2.40	0.09	0.09	0.08
	(0.54)	(0.55)	(1.11)			
Investment	-3.04	-4.06	-1.97	-1.04	-1.27	-0.79
	(1.36)	(1.73)	(2.09)			
Net Exports	0.47	0.36	0.65	0.57	0.50	0.65
	(0.35)	(0.53)	(0.30)			
Exchange Rate	0.54	-0.13	1.48	-0.24	-0.03	-0.45
	(0.56)	(0.47)	(1.30)			
GDP Growth	-0.26	-0.37	-0.14	-0.10	-0.14	-0.06
	(0.11)	(0.16)	(0.10)			

Notes: Table displays data and model results for the multiplier α in regression (II.3).

4.2 Benchmark Model Performance

We can now compare the benchmark model with the earlier empirical results. The left panel of Table II.7 shows the empirical relationship between the austerity shocks (negative shocks to government purchases) and our five measures of economic performance. These results are identical to the estimates in Table II.4. The right panel of Table II.7 shows the results for the same regression (II.3) but run on the simulated data. Several points are worth emphasizing. First, the estimated effects of the austerity shocks are substantially smaller than the estimates from the data. Empirically, the government purchase multiplier on GDP is 1.37. In contrast, the model estimates suggest a multiplier of only 0.63, less than half the size. Similarly, the inflation reactions are also not of the same magnitude. A reduction in government purchases of one percent of GDP is associated with a small reduction in inflation of roughly 0.14 percent, with a somewhat stronger effect for fixed exchange rate countries. The model implies an even weaker reduction of 0.03 percent for fixed exchange rate countries, but an increase of 0.03 percent for floating exchange rate countries.

As one would anticipate, the model with complete markets fails in generating movements in consumption in response to government purchase shocks. If anything, the model implies a crowding-out effect on consumption, with reductions in government purchases leading to slightly increased consumption. Interestingly, the model predicts a negative response of investment to government purchase reductions, although, again the response is less than half as big as the one in the data. In contrast, net exports are positively associated with reductions in government purchases in both the data and the model.

Figures II.4 - II.10 show comparisons of scatterplots of the actual data (left panels) and the scatterplots of simulated data (right panels). For each panel, the log austerity shocks (i.e., forecast errors) are on the horizontal axis. The units of both axes are log points times 100. The panels also show the OLS regression lines for the fixed exchange rate countries (the solid dots) and the floating exchange rate countries (the open dots).

The figures reveal several differences between the actual data and the model. First and most importantly the actual data has substantially more noise than the model simulations. This is not surprising since the model includes only a limited number of shocks. Second, the inflation data exhibits substantially more variation across countries within the Eurozone than the model permits. In the model, even though there are sharp differences in government spending across countries, there is a strong tendency for countries in the currency union to have inflation rates that are nearly the same. On the other hand, the model displays substantial swings in inflation for countries that are not in the Eurozone while in the data, inflation does not differ radically from that of the Eurozone. This may be due to the fact that even though these countries technically have floating exchange rates and independent monetary policy, the monetary authorities in these countries do not depart from the policies enacted by the ECB. Third, the exchange rate data display only a very weak relationship to austerity shocks. In the model, exchange rates in the Eurozone display virtually no variation across countries (recall, these are trade-weighted

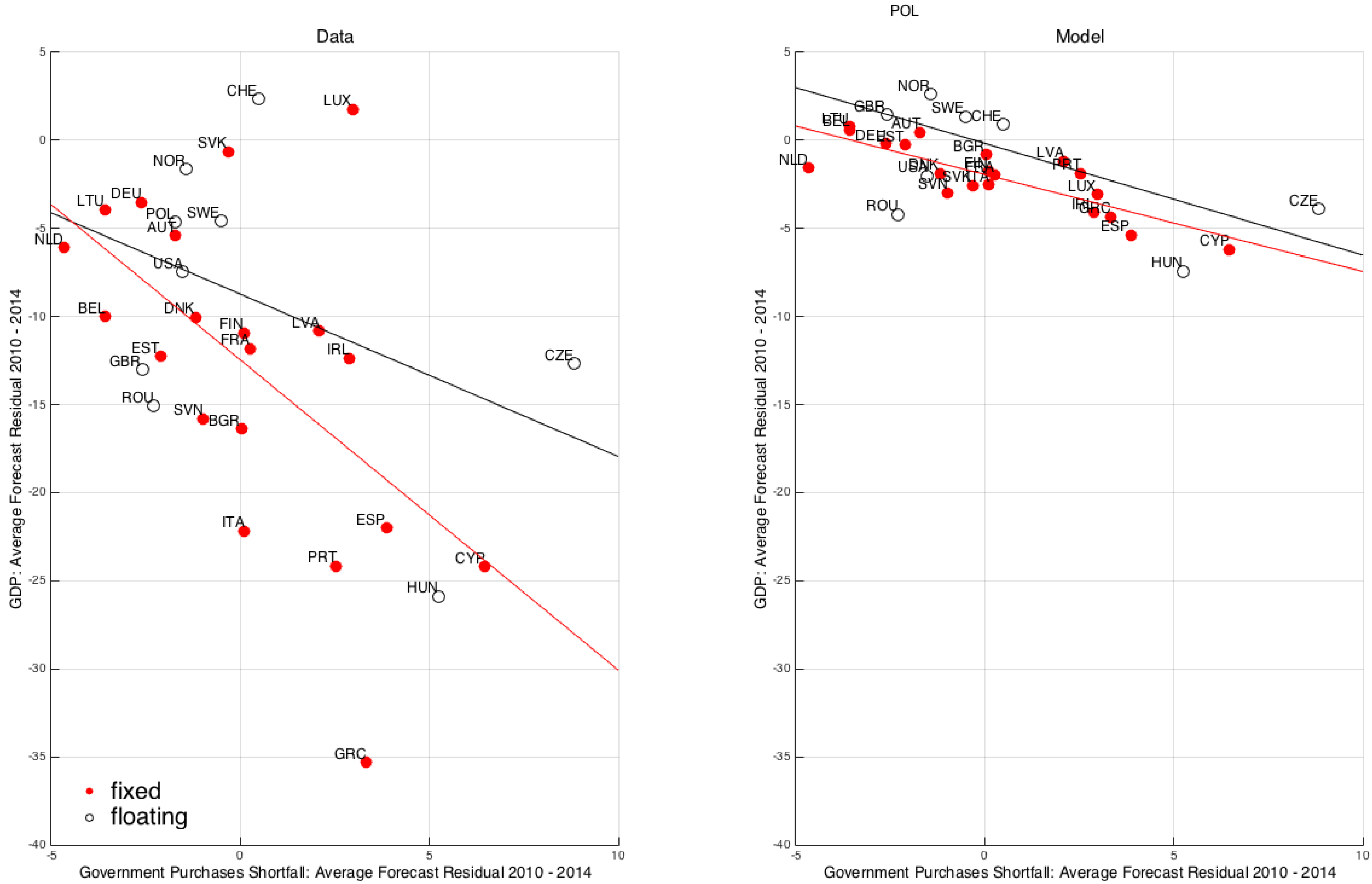


FIGURE II.4: GDP AND AUSTERITY: DATA VS. MODEL

Note: Figure displays a scatter plot of the average forecast residual of GDP over 2010 - 2014, in log points, versus the average forecast residual for the shortfall in government purchases, also in log points. Countries are classified by their exchange rate regime (red: euro / pegged to euro; black: floating currency). Regression lines are based on data points from each exchange rate regime. Left panel is based on actually observed data; right panel refers to data from the simulated model. See text for details on the forecast specification.

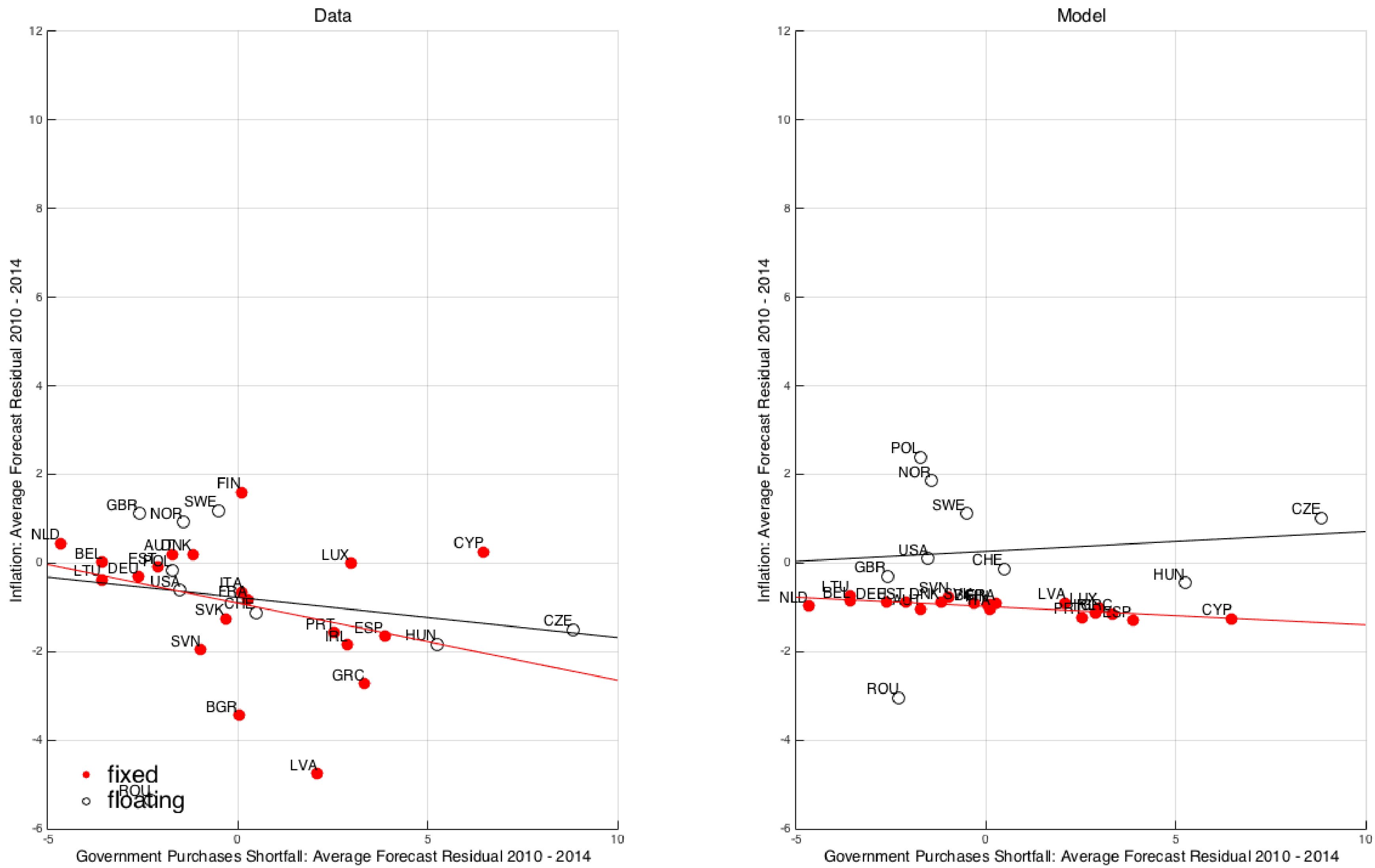


Figure II.5: Inflation and Austerity: Data vs. Model

Note: See Figure II.4.

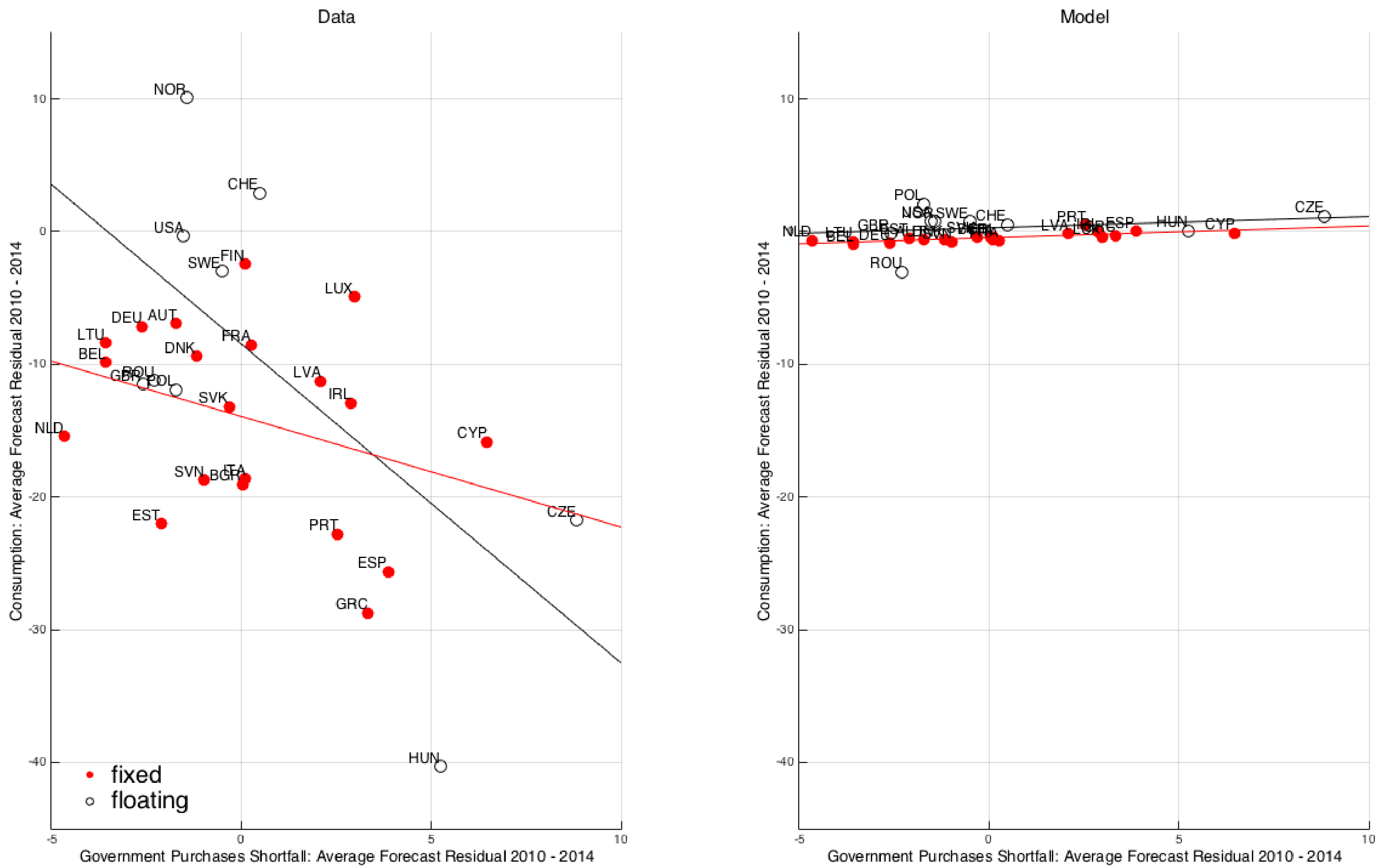


Figure II.6: Consumption and Austerity: Data vs. Model

Note: See Figure II.4.

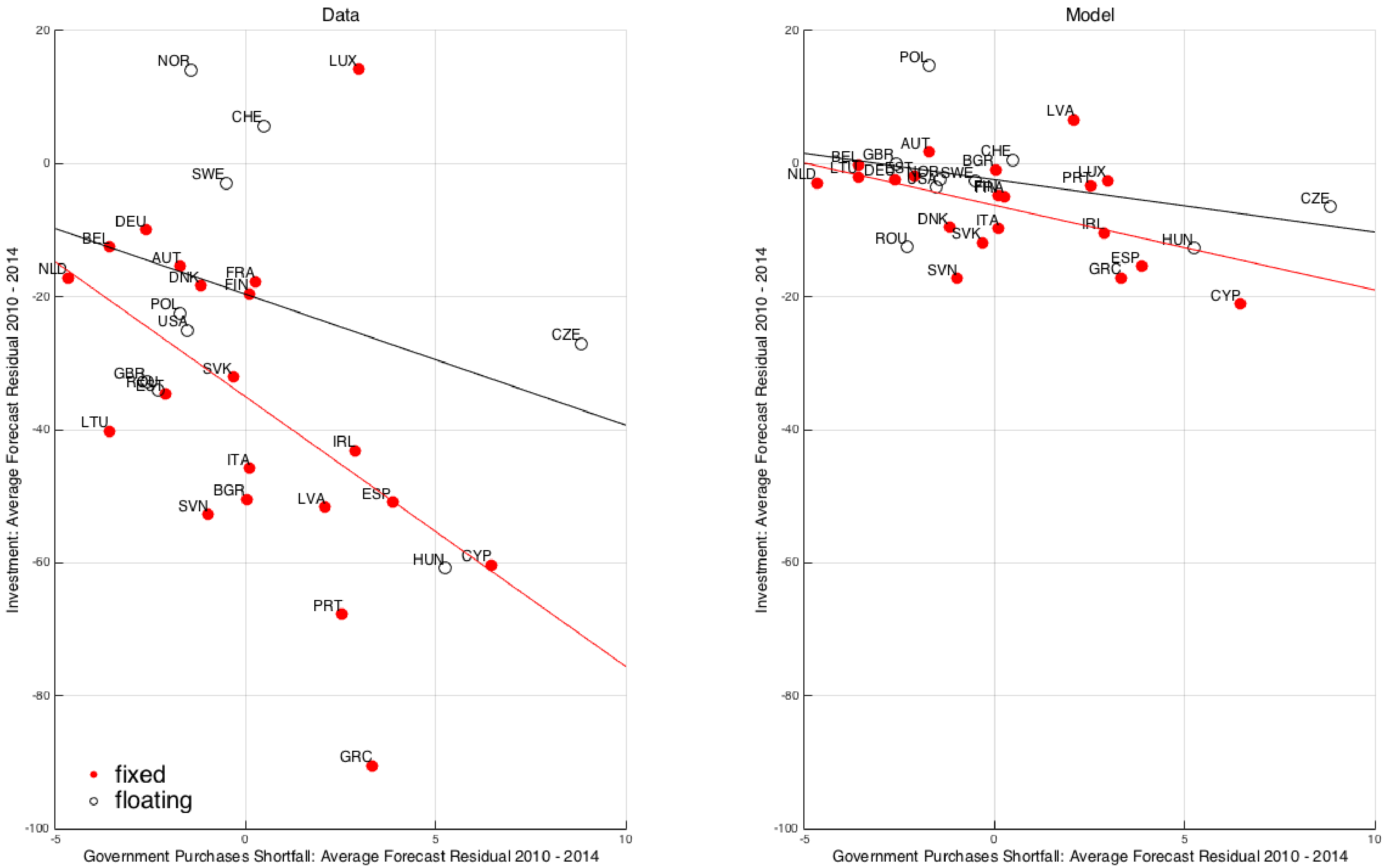


Figure II.7: Investment and Austerity: Data vs. Model

Note: See Figure II.4.

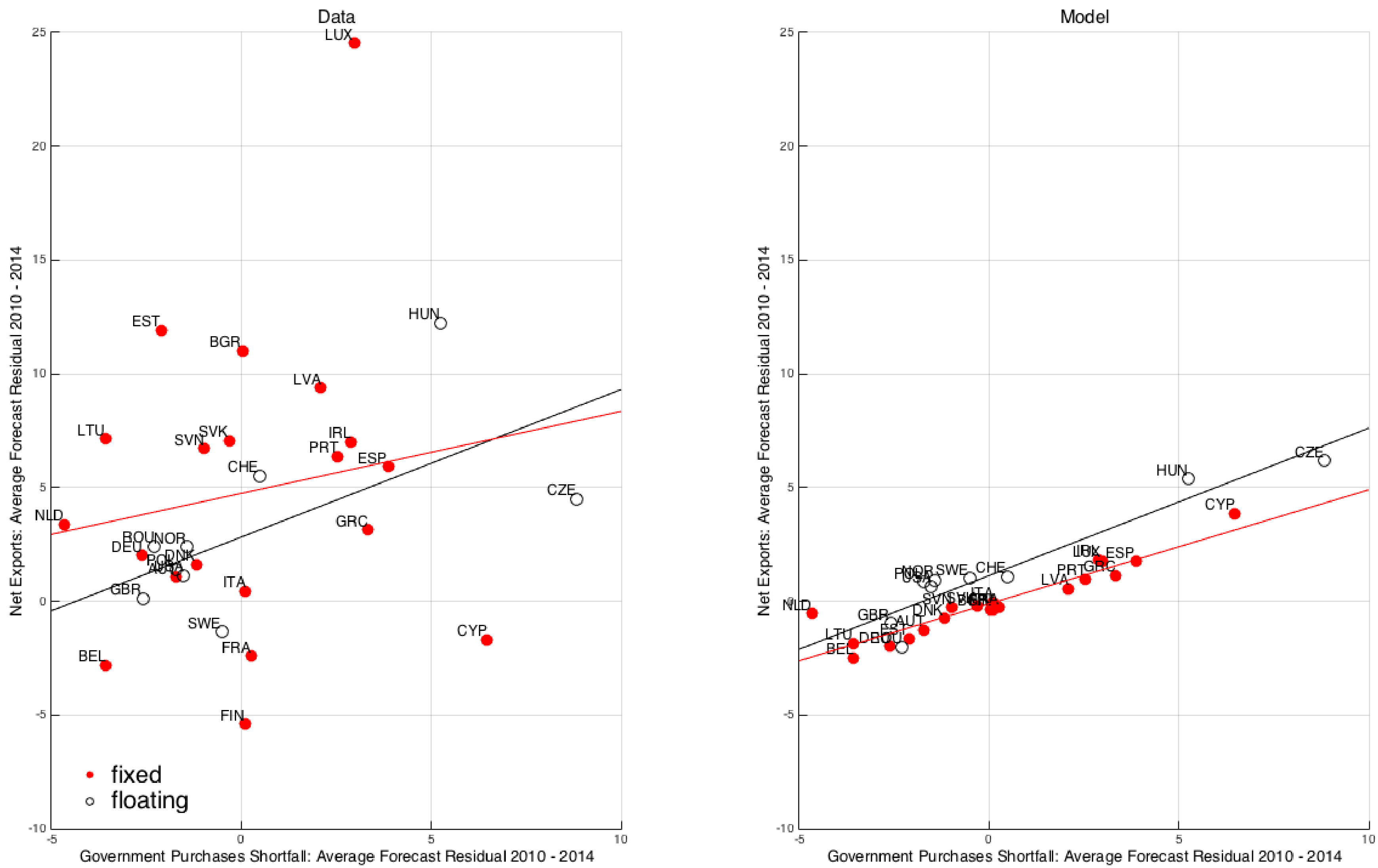


Figure II.8: Net Exports and Austerity: Data vs. Model

Note: See Figure II.4.

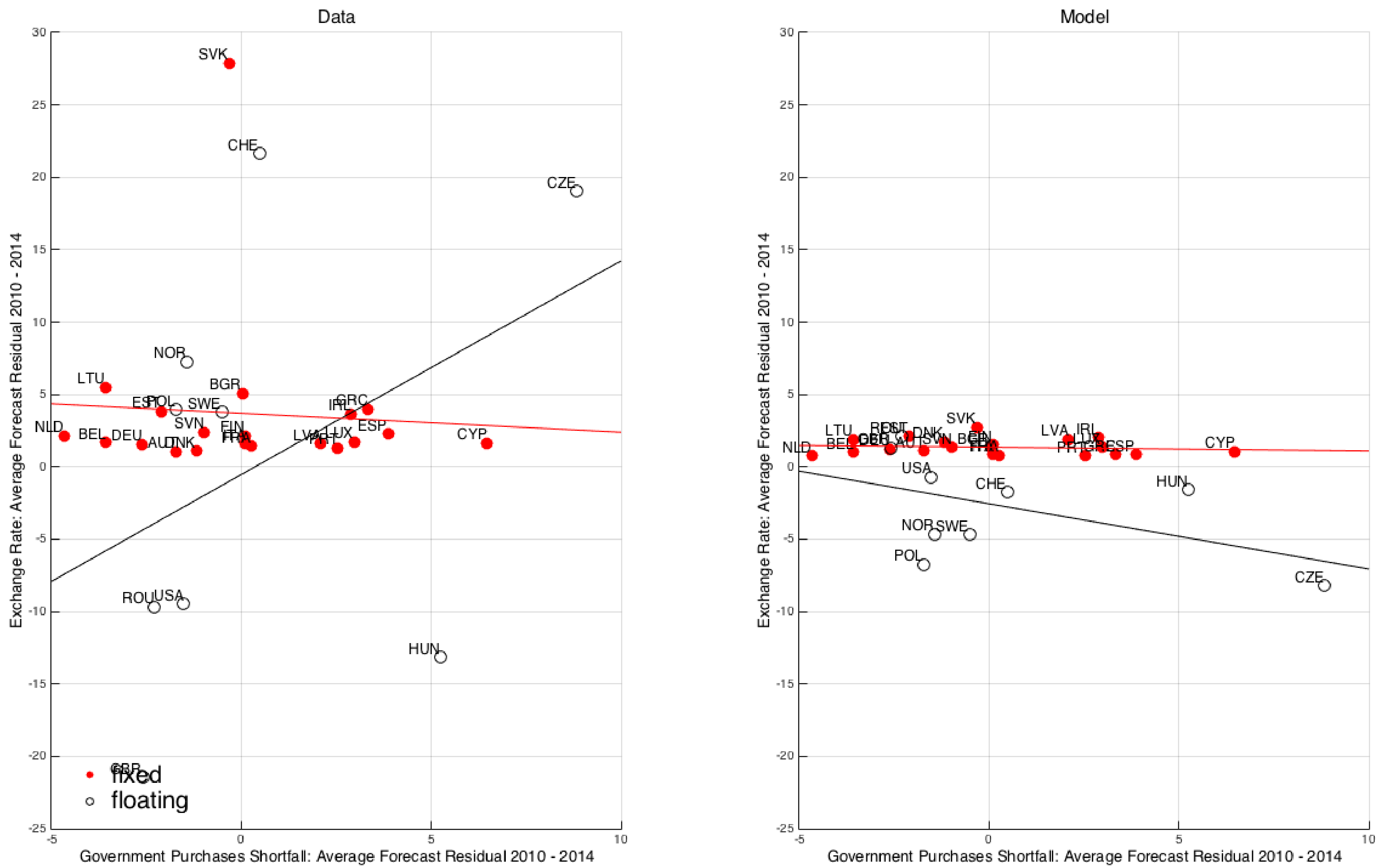


Figure II.9: Nominal Effective Exchange Rate and Austerity: Data vs. Model

Note: See Figure II.4.

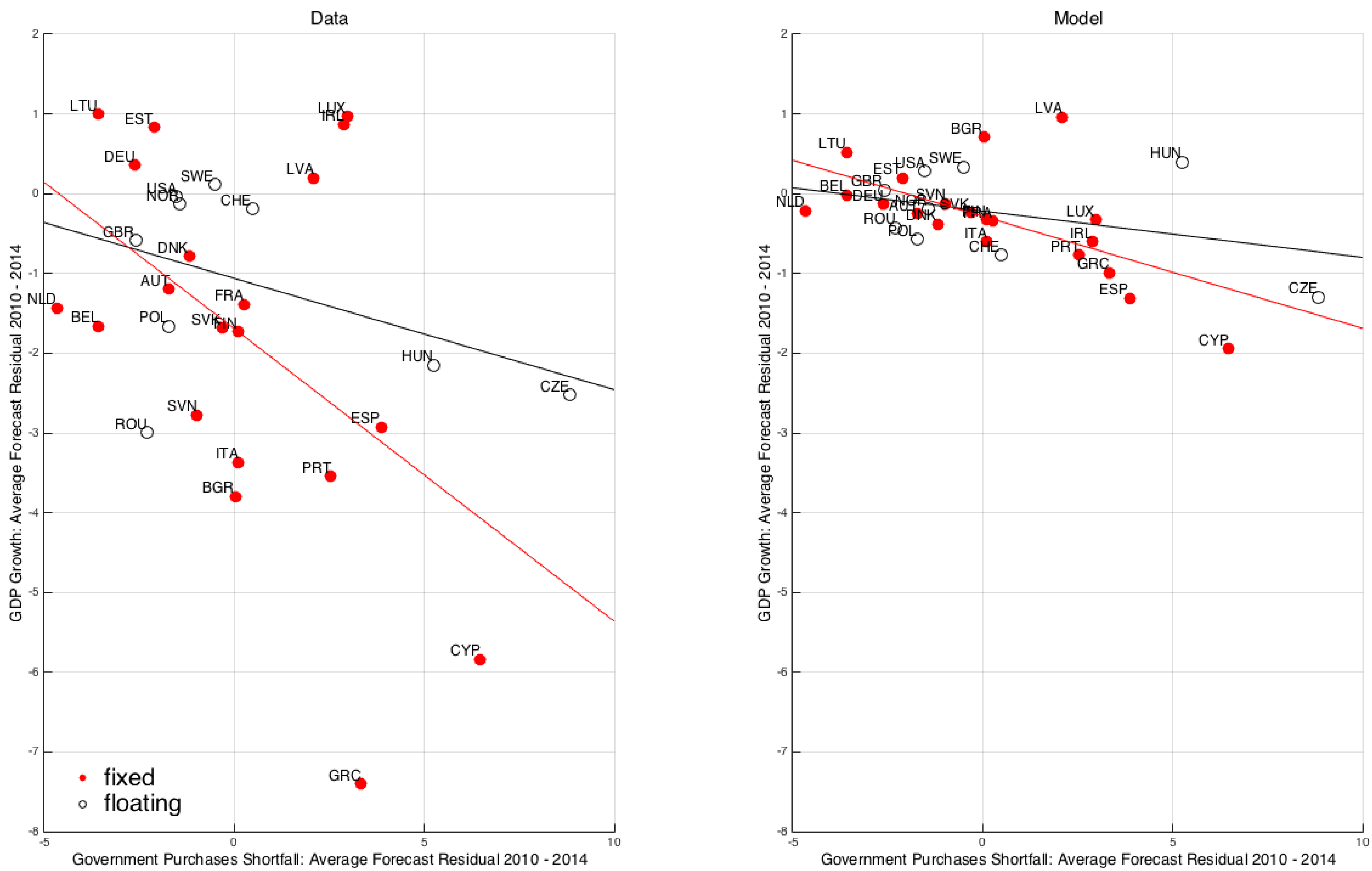


FIGURE II.10: GDP GROWTH AND AUSTERITY: DATA VS. MODEL

Note: See Figure II.4.

exchange rates and thus countries in the Eurozone can have changes in their exchange rate).[28]

To understand the mechanisms operating in the model, we examine the model's reaction to variation in each of the three forcing variables—austerity, monetary shocks, financial shocks—separately. Table II.8 reports the results of such a decomposition. It displays the regression coefficients for the seven measures of economic performance. The two left most panels report the data and the results for the benchmark model; the three other panels report the results for each shock separately. The explanatory variable in all regressions are the government purchase shocks as they are observed in the data and fed into the benchmark model. The decomposition reveals two things: First, the negative relationship between austerity and performance in the model is only partially driven by austerity. Countries that are empirically identified as austere were also hit by contractionary monetary policy and spread shocks. For countries with a floating exchange rate, the negative austerity-performance relationship derives to an important extent from austere countries implementing contractionary monetary policy.

Second, while the benchmark model produces regression coefficients that are qualitatively consistent with those observed in the data, this is not true for the individual shocks. Both austerity and monetary policy shocks are needed to generate patterns as those observed in the data. Austerity shocks lead to declines in GDP and rising net exports as in the data, but also produce counterfactual inflation in floating exchange rate countries and a depreciation of their exchange rates. Monetary policy shocks help explain the pattern of inflation and exchange rates in floating exchange rate countries, but—not surprisingly—cannot explain the variation observed across fixed exchange rate countries. We now explain the effects of these two shocks in the model.

A reduction in government spending leads to a fall in GDP through a reduction in employment. Firms respond to the drop in demand for their goods by reducing their demand for labor. On the households' side, the contraction in government spending has a positive effect on wealth, and households respond by increasing their demand for goods and reducing their supply of la-

[28]Slovakia is a clear outlier in the scatter plot in Figure II.9. This is because Slovakia was actively bringing its exchange rate into alignment with the Euro after 2005 (when our unit root forecast starts) and before it adopted the euro in 2009.

TABLE II.8: COMPARISON OF MODEL AND DATA: INDIVIDUAL SHOCKS

	Data			Benchmark			Only Govt			Only Money			Only Spread		
	All	Fix	Float	All	Fix	Float	All	Fix	Float	All	Fix	Float	All	Fix	Float
GDP	-1.37	-1.76	-0.92	-0.58	-0.55	-0.63	-0.46	-0.48	-0.44	-0.13	0.01	-0.34	-0.06	-0.10	-0.01
	(0.48)	(0.62)	(0.74)												
Inflation	-0.14	-0.17	-0.09	0.00	-0.04	0.04	0.08	-0.05	0.23	-0.10	-0.00	-0.24	0.00	0.01	0.00
	(0.10)	(0.11)	(0.19)												
Consumption	-1.48	-0.83	-2.40	0.09	0.09	0.08	0.11	0.08	0.14	-0.04	-0.00	-0.11	0.01	0.01	0.01
	(0.54)	(0.55)	(1.11)												
Investment	-3.04	-4.06	-1.97	-1.04	-1.27	-0.79	-0.53	-0.61	-0.43	-0.29	0.01	-0.71	-0.58	-0.87	-0.21
	(1.36)	(1.73)	(2.09)												
Net Exports	0.47	0.36	0.65	0.57	0.50	0.65	0.57	0.46	0.72	-0.04	0.01	-0.11	0.04	0.05	0.03
	(0.35)	(0.53)	(0.30)												
Exchange Rate	0.54	-0.13	1.48	-0.24	-0.03	-0.45	-0.24	-0.00	-0.54	0.09	-0.01	0.27	-0.01	-0.01	-0.01
	(0.56)	(0.47)	(1.30)												
GDP Growth	-0.26	-0.37	-0.14	-0.10	-0.14	-0.06	-0.09	-0.12	-0.04	-0.01	0.00	-0.02	-0.02	-0.03	-0.01
	(0.11)	(0.16)	(0.10)												

Notes: Table displays data and model results for the multiplier α in regression (II.3). The benchmark calibration includes shocks to government spending, the Taylor rule and interest rate spreads. The following columns display results if only one of those shocks is fed into the model.

bor. On net, the contraction in government expenditures results in excess supply of the home good; the real exchange rate depreciates and net exports increase.

The effect on inflation is ambiguous. Inflation is forward looking and depends on the future path of real marginal costs, including wages. Wages will be low if the reduction in labor demand outweighs the fall in labor supply. This is typically the case under fairly standard parameterizations of a closed economy New Keynesian model (including a closed economy version of our model), so that reductions in government spending cause deflation. In our open economy setting, however, reductions in government spending can cause inflation for countries with floating exchange rate (see the coefficient for inflation, 0.23, in Table II.8 in the 'Only Govt' panel). This is because of the exchange rate: In response to a fall in government spending, the nominal exchange rate depreciates (see the coefficient -0.54). This raises the price of imports and stimulates demand for exports, which counterbalances the fall in labor demand and prevents wages from falling (too much). Both effects cause inflation.

Although our model features only limited risk sharing, increases in consumption translate into a depreciation of the real exchange rate in both fixed and floating exchange rate countries. For fixed exchange rate countries, the depreciation of the real exchange rate is achieved through deflation. For floating exchange rate countries, the depreciation of the real exchange rate comes from a depreciation of the nominal exchange rate (despite inflation).[29]

As mentioned above, the implied response of inflation and exchange rate for floating exchange rate countries is counterfactual in the experiment with government spending shocks only. Adding monetary policy shocks improves the model's performance along these dimensions. In particular, in our dataset empirically austere countries tend to have interest rates above the level suggested by the Taylor rule. These high interest rates reduce consumption and output, push down inflation and lead to an appreciation of the nominal (and real) exchange rates.

[29]This is at least partially caused by our choice that prices are sticky in the producer's currency (as opposed to the buyer's currency).

4.3 Variations on the Benchmark Model

The simulations displayed in Figures II.4 - II.10 and the results in Tables II.7 and II.8 all correspond to the benchmark parameterization described in Table II.6 with government spending shocks (i.e., austerity shocks), monetary policy shocks and financial shocks included as forcing variables. Here we briefly consider some variations of our preferred specification to show whether the model results depend crucially on particular assumptions.

5 Counter-Factual Policy Simulations [to be completed]

The model with government spending shocks, monetary policy shocks and financial shocks generate cross-sectional results that are broadly consistent with the observed economic outcomes in Europe and the United States in the 2010-14 period. We next use the model as a laboratory for considering some counterfactual scenarios and to conduct policy experiments. The model makes it possible to assess the costs and benefits of alternative policy options and illuminates the channels through which national policies are transmitted to other economies. Among the policy experiments we consider include:

• Alternative fiscal policies. The model will make it possible to examine different policy mixes (i.e. varying composition of expenditures and taxes) as well as changes in the timing of fiscal policy.

• Alternative specifications of the Taylor rule, allowing for more aggressive responses to output and unemployment in different countries. Among the questions the framework will allow us to address is whether a more aggressive monetary policy response immediately following the global financial crisis would have lessened the depth of the recession in Europe. Another potential experiment is the impact of a monetary policy response that places a greater weight on periphery countries than that implied by their relative size.

• Outcomes under floating exchange rates with independent monetary policies. The model will make it possible to assess in quantitative terms the costs and benefits of the constraint imposed by the common currency and a shared monetary policy.

• The model captures the importance of trade and financial markets. By varying the degree of openness it will be possible to explore the importance of such linkages for the transmission of shocks across national boundaries.

• The relative importance of monetary vs. fiscal policy as a mechanism for responding to external shocks. The model will make it possible to quantify the impact of alternative policy instruments.

• Coordinated fiscal policy. The quantitative model will make it possible to assess the trade-offs of unilateral versus coordinated policy responses.

• The cost of debt overhang. The model will make it possible to examine the constraint imposed by government debt operating through alternative specifications of fiscal rules.

The negative macroeconomic repercussions of the recent financial crisis were felt in both the United States and Europe. Many economists have argued that the slow pace of recovery in many European countries is a direct consequence of the macroeconomic austerity policies pursued by different governments. By undertaking a retrospective analysis of the policy responses to the financial crises, this research will make it possible to evaluate the role that austerity played in limiting the pace of the economic recovery. The theoretical model will enable researchers to evaluate the impact of alternative policies under different conditions. The research will therefore provide both theoretical and empirical guidance for government policies designed to affect overall economic performance.

6 Conclusion

Since the end of the Great Recession in 2009, European countries have experienced radically different recoveries. Some enjoyed a return to normal economic growth shortly following the financial crisis while others have suffered through prolonged periods of low employment and low growth. We have attempted to make sense of this diversity of experiences by examining empirical comovements for various measures of economic activity for the nations of Europe. Despite substantial noise in the data, there are clear patterns that suggest that a surprising amount of the differences in economic performance are due to austerity policies. In particular, the evidence suggests that contractions in government spending have played a surprisingly large role in reducing output for some countries. Evidence for tax policies and the primary balance is more mixed. Countries that increase taxes fare worse than otherwise but the effects of raising taxes are modest and not strongly statistically significant. In contrast, countries that reduce government spending experience sharp reductions in output and inflation.

We use a multi-country DSGE model to see whether standard macroeconomic theory can make sense of the observed changes in economic activity. The model features government spending shocks, monetary policy shocks, and shocks to financial markets and allows us to make direct comparisons between the observed empirical relationships in the data and the model's predictions. The model is calibrated to match the main features of the European countries in our dataset including country size, observed trade flows and exchange rate regimes. The model output broadly matches the empirical patterns observed in the data. While our preliminary findings suggest that standard Keynesian mechanisms are playing a strong role in shaping the behavior of countries across Europe, the quantitative predictions of the model for GDP are too small to fully match the empirical findings. This likely means that the magnitude of the demand multipliers in the model are simply too weak to match the data. Future work is needed to refine the model's performance along this dimension.

Chapter III

Survival of the Fittest: Corporate Control and the Cleansing Effect of Financial Crises[1]

1 Introduction

Since Joseph Schumpeter's classic work on competition, innovation and growth in modern economies (Schumpeter, 1942), a large literature has investigated the so-called cleansing effect of recessions. Described simply, the cleansing effect works by forcing the exit of the least productive firms and reallocating resources to the most productive firms following adverse aggregate shocks, thereby raising the average productivity of the aggregate economy. What is often overlooked in this literature is that distressed firms need not exit, but may be acquired by other domestic or foreign firms through the process of mergers and acquisitions (M&As).[2]

In this paper we analyze the effects of an aggregate negative financial shock on the market for

[1]This chapter is collaborative work with Rahul Mukherjee.

[2]The global M&A market has grown tremendously in the last three decades, and stood at roughly 3.7 trillion USD in 2007. Cross-border M&As have also kept pace, peaking in 2007 at 1.032 trillion USD starting from 0.098 trillion USD in 1990. For the last year for which data is available (2014), they stood at 0.398 trillion USD. These numbers are from the latest edition of the World Investment Report (UNCTAD, 2015).

corporate control, and through it, the aggregate economy. In a nutshell, our main finding is that major financial shocks, like systemic banking crises, have profound effects *in* and *through* the market for corporate control. By "in", we mean the changes that occur in the characteristics of the acquisitions that are completed during financial crises; while "through" refers to the effects that M&As have on the productivity of the aggregate pool of firms following a financial crisis. In particular, we show that domestic and foreign acquisitions in countries hit by financial shocks differ markedly along these two aspects.

Our focus on financial shocks is motivated by recent work that demonstrates the importance of financial factors as drivers of M&As (Almeida et al., 2011; Erel et al., 2015), as well as the literature that focusses on financial crises as drivers of domestic and cross-border M&As, especially in emerging markets (Aguiar and Gopinath, 2005; Acharya et al., 2011; Alquist et al., 2016). This literature has noted that financial crises in emerging market economies are accompanied by a sharp rise in foreign M&A activity, and a concurrent decline in domestic acquisitions. Figure III.1 shows this phenomenon succinctly by plotting the number of foreign and domestic acquisitions (standardized and detrended as explained below) in a sample of emerging market economies within a four-year event window of systemic banking crises in these countries.[3] While the role of financial liquidity in driving the stylized fact portrayed in Figure III.1 is generally acknowledged, little is known besides on the *differences* between foreign and domestic M&A activity, as well as the differential effects of foreign and domestic M&As on the aggregate allocation of resources, in the face of aggregate financial shocks.[4] Our paper sheds light on these issues, and as such, has three main contributions, two theoretical and one empirical.

[3]To construct this graph, we first count the number of domestic / foreign acquisitions per target country and year. We then standardize this number by its country-specific time-series average. We detrend the standardized numbers by regressing them, for each target country separately, on an intercept plus a linear time trend (adding a log time trend leaves our results basically unchanged). We then calculate the country-specific mean of the detrended numbers of acquisitions for three time periods: (i) four non-crisis years before a crisis, (ii) all crisis years, and (iii) four non-crisis years after a crisis. The figure displays, for each time period, the average across countries weighted by the average number of acquisitions per country. Includes only those countries that had at least one domestic and one foreign acquisition event during a systemic banking over the period 1990-2007. The full sample of countries is described later.

[4]One notable exception is the paper by Aguiar and Gopinath (2005), which notes that firm level liquidity was a better predictor of the probability of a foreign acquisition than the probability of a domestic acquisition in the tradable good sector during the Asian Financial Crisis of 1997-98.

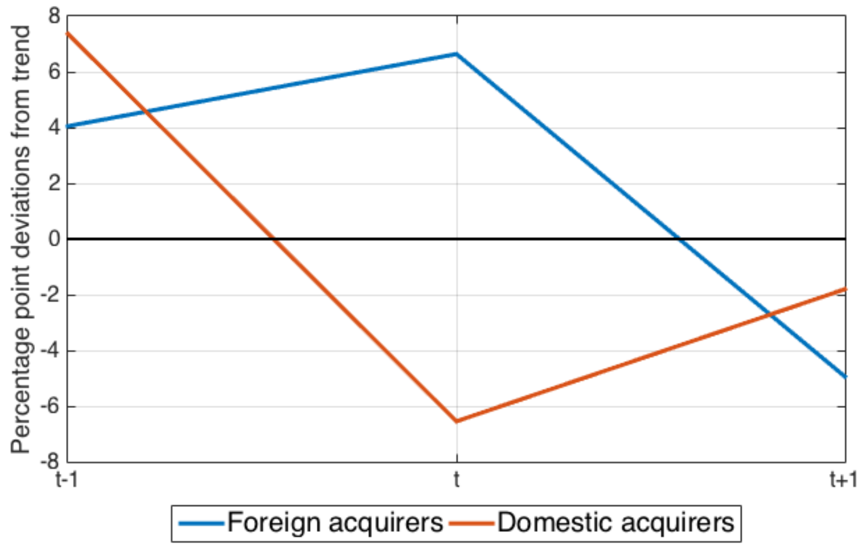


Figure III.1: Number of Acquisitions

Note: Figure displays the percentage point deviations from trend for the number of foreign and domestic acquisitions. The time periods correspond to pre-crisis years ($t-1$), crisis years (t) and post-crisis years ($t+1$). The number of acquisitions are standardized and detrended for each country separately and then averaged across target countries, weighted by the average of number of acquisitions per country. See text for details.

Our first contribution is to develop a simple analytical framework that allows both financially constrained and financially unconstrained acquirers to engage in M&As. In our model, firms face borrowing constraints, which make it harder for some firms to pay upfront fixed costs of operating, and make them more likely to exit. Other firms with more financial resources can step in and buy them and thus prevent inefficient liquidation. However these acquiring firms may themselves have to raise funds to finance their acquisition if their internal resources are not sufficient for the purpose.

Target firms that would not be viable by themselves are acquired if they are sufficiently productive (it is not worthwhile to acquire firms below a certain productivity since acquirers are unable to recoup acquisition costs), and exit otherwise. We label these acquisitions as “fire-sale” acquisitions since these are distressed assets whose value to a new owner capable of paying the fixed cost exceeds their valuation in the eyes of the current owners. “Technology-driven” acquisitions, on the other hand, involve those high-productivity target firms that are worth acquiring no matter what their financial situation, and as such, may include target firms that are financially distressed due to temporary liquidity shortages. Our model has two additional features. First, fire-sale acquisitions are on average less productive than technology-driven ones because part of the surplus in these acquisitions is driven by the relaxing of borrowing constraints. Second, the higher the productivity of an acquirer-target match, the larger is the stake acquired in target firms because of variable acquisition costs. In this setup, we analyze the consequences of a negative aggregate financial shock that tightens the borrowing constraints of all firms in the economy, including potential acquirers.

To build intuition, first consider the case of those acquiring firms that are unconstrained under all circumstances. We can think of these as foreign firms involved in cross-border acquisitions that are based in markets that have not faced the financial shock (e.g., the inflow of foreign capital shown in Figure III.1). These could also be very large domestic firms that have enough internal funds of their own. The shock raises the share of fire-sale acquisitions in the total number of acquisitions they undertake, as a larger proportion of potential target firms find themselves unable to raise enough external debt financing to cover fixed expenses. Since fire-sale acquisitions correspond to lower values of productivity than technology-driven acquisitions, this lowers the average long-term productivity of the acquisitions made by unconstrained acquirers. We derive analytical results about this extensive margin, which refers to the change in the composition of acquisitions between fire-sale and technology-driven, and show that it unambiguously lowers the average productivity of the acquisitions completed by unconstrained acquirers during financial crisis episodes.

Things are less straightforward when acquiring firms themselves are financially constrained. While a negative financial shock can increase the mass of fire-sale acquisitions performed by constrained acquirers as well, thereby lowering the average productivity of their acquisitions, there is an additional force in their case that tends to work in the opposite direction. This force is the result of the combination of a fixed cost of acquisition and the presence of financial frictions. The presence of a fixed cost of acquisition means that acquisitions among more productive acquirer-target entities are more profitable than acquisitions among low productive ones. Credit market frictions reinforce this disadvantage of acquisitions between low-productivity firms. This makes acquisitions among low-productivity firms even less profitable because the fixed cost weighs relatively more on their borrowing constraint. This disadvantage for low-productivity firms is small during normal times when borrowing constraints are loose, but becomes stronger when borrowing constraints tighten during a negative financial shock. As a result, financial crises do not only increase the pool of distressed target firms, but they also make acquisitions less likely because acquiring firms face tighter borrowing constraints, and this is particularly true for low-productivity acquirers.

This has two consequences for the change in the average productivity of acquisitions undertaken by constrained firms: First, the share of fire-sale acquisitions might not go up because the firms acquiring those distressed targets have a low productivity themselves and face particularly tight borrowing constraints themselves. Thus the overall extensive margin in the case of constrained acquirers may move either way. Second, within each group of fire-sale and technology-driven acquisitions, it is the least productive acquisitions that become particularly less feasible. This is an intensive margin that raises the average productivity of the acquisitions that are actually completed.

In order to quantitatively evaluate the net effect of these two margins, we calibrate the model to match three key first moments of a data set on emerging market M&As – the average share of a firm acquired, the proportion of acquisitions in which the entire target is acquired, and the average size difference between domestic acquirers and their targets – and then simulate a tightening of the borrowing constraint for all firms in the economy. We find that the intensive margin dominates in the case of constrained acquirers, so that the average productivity of acquisitions rises in the aftermath of an adverse aggregate financial shock. This is a central insight of our analysis: The average productivity of acquisitions completed by constrained acquirers improves during financial crises. If the financially constrained firms be interpreted as domestic firms in crisis-hit economies, then our analysis suggests that acquisitions completed by domestic firms during financial crises are more productive on average, in contrast to unconstrained acquirers (foreign firms). This is, there is a "cleansing effect" in the market for corporate control, whereby aggregate financial shocks lead to an increase in the average productivity within the group of firms that become targets of domestic acquirers.

There are two sets of observable implications, differing across unconstrained (foreign) and constrained (domestic) acquirers, of the mechanisms outlined above. The first is that the average share of equity acquired by domestic acquirers should rise during financial crises, while the opposite should be true for foreign acquirers. Second, the model predicts that the divestiture rates for domestic acquisitions should be lower for the crisis cohort of domestic acquisitions, while the opposite should be true for foreign acquisitions. To the extent that the divestiture rates of foreign acquisitions is lower than for domestic acquisitions during normal times (which, as we show later is a feature of the data), the above two predictions jointly imply a convergence in divestiture rates between foreign and domestic acquisitions for the crisis cohort. It is worth emphasizing here that all our contrasting theoretical results for foreign and domestic acquisitions originate in the assumed differences in firm level borrowing constraints between them. This one dimensional difference between firms is a deliberate modelling choice meant to highlight the role of liquidity constraints in the M&A process.

Our second contribution is empirical. We test the predictions of the model using data for about 30,000 foreign and domestic M&As for sixteen of the largest markets for corporate control in emerging economies between 1990 and 2007 from the Thompson-Reuters SDC database. We focus on emerging markets because we expect domestic firms there to conform more closely to the constrained firms of the model. Due to the structure of our hypotheses, which involve comparisons of two kinds of acquisitions (relatively financially constrained and unconstrained acquisitions, proxied by those made by domestic and foreign acquiring firms, respectively), across two macroeconomic regimes (normal times and adverse financial shocks, the latter proxied by the occurrence of country-specific banking crises), we employ a difference-in-difference approach. Using linear regressions and survival analysis techniques, we find evidence in favor of the main predictions of the model. In particular, we find that domestic acquisitions during crises involve significantly higher stakes, in contrast to foreign acquisitions. The survival rates of foreign acquisitions completed during normal times are found to be higher than domestic ones. However, the survival rates of domestic acquisitions are significantly higher for the cohort of crisis-time acquisitions – a consequence of the cleansing effect – which implies a convergence in the divestiture rates of foreign and domestic acquisitions.[5]

Our third contribution is purely theoretical. While the above results pertain to the group of firms that are actually acquired, our model also has predictions on the average productivity of all firms that survive an adverse financial shock, and hence, on the aggregate cleansing effect of financial crises. First, it is important to note that our model lacks a cleansing effect of adverse financial shocks when we do not allow distressed firms to be acquired. This is due to our assumption that financial constraints do not depend on firm size, and long-term productivity and temporary liquidity are uncorrelated: all firms in our model, whether they are productive or unproductive, are equally likely to exit in a financial crisis, leaving aggregate productivity unchanged. While this might be unrealistic, these two modeling assumption are deliberate and meant to isolate the pure effect of the introduction of a market for corporate control. We show that the presence of unconstrained (foreign) acquirers leads to a positive cleansing effect of a financial shock due to "cream skimming": Fixed costs of acquisitions imply that foreign firms acquire (and save from exit) only firms that are above a certain level of productivity.[6] In contrast, we show that acquisitions by firms that are themselves financially constrained lead to a positive but small aggregate cleansing effect: These firms, being themselves constrained, are unable to save high-productivity firms that are illiquid.[7] These results also shed light on the extent to

[5]These empirical results are robust to alternative samples and definitions of aggregate financial shocks, the inclusion of macroeconomic variables that control for normal business cycle variation in acquisition activity, country×industry fixed effects that control for time-invariant international differences across broad groups of industries, and non-linear estimation procedures.

[6]Note here that while the average productivity of firms *acquired* by unconstrained acquirers during financial crises is lower because more low-productivity firms get acquired (our first set of results), the average productivity of the *overall* population of surviving firms goes up because acquired firms are, on average, more productive than the population of producing firms.

[7]Once again, note that this result pertains to the aggregate effects of a financial shock in the presence of constrained (domestic) acquirers, and is thus perfectly consistent with our earlier set of results that showed that the firms acquired by domestic acquirers during financial crises would have higher productivity on average.

which a flourishing market for M&As can, through reallocation of liquidity between firms, substitute for local credit markets: Under our baseline calibration, an economy without any credit markets sees its productivity increase by 1.8 percent if domestic acquisitions are possible, but by more than 35 percent if it opens up to foreign acquisitions.

The rest of the paper is organized as follows. The following section briefly reviews the literature and outlines our contributions. Section 2 lays out a theoretical model of M&As, and derives some testable hypotheses that we take to the data in Section 3. Section 4 concludes.

1.1 Related Literature

Our paper contributes to two broad strands of literature in macroeconomics and finance. The first concerns the cleansing effect of recessions and capital reallocation over the business cycle. This literature has explored several mechanisms in connection with the cleansing effect, related to labor markets (Caballero and Hammour, 1996), entrepreneurial credit constraints (Holtz-Eakin et al., 1994), and the contribution of new producers' productivity advantages and entry (Foster et al., 2008). Here, the closest paper to ours is Osotimehin and Pappadà (forthcoming), who look at how credit constraints influence the cleansing effect of recessions in a theoretical model of firm dynamics. They find that the intensity of the cleansing effect is lower in the presence of credit frictions, especially when the recession is driven by a financial shock. The exit decision of firms in their model depends not only on their productivity but also their net worth, and hence some firms that are productive yet financially distressed exit the market while some low productivity firms do not. Eisfeldt and Rampini (2006) explore the procyclicality of capital reallocation among firms, and the apparent countercyclicality of the benefits from reallocation. Their analysis suggests that the cost of capital reallocation needs to be strongly countercyclical to rationalize the observed joint cyclical properties of reallocation and productivity dispersion. In a similar vein, Cui (2014) develops a dynamic general equilibrium model where partial capital irreversibility generates delays in capital reallocation during periods when credit conditions are tighter and lowers aggregate productivity. Thus there is a large literature that puts forward various channels that either strengthen or weaken the basic mechanism of the aggregate cleansing effect. Our contribution to this literature is theoretical. As outlined earlier, we show that the presence of a market for corporate control has important consequences for the aggregate cleansing effects of financial crises. In particular our results suggest that the market for corporate control is a substitute for credit markets, so that when frictions in the credit market go up – leading to misallocation and firm exit based on liquidity rather than productivity – the presence of a corporate control market can attenuate these effects and improve resource allocation.[8]

Our paper is also related to a more recent literature on the financial determinants of M&As. Almeida et al. (2011) present a model in which financially distressed firms merge with more liquid firms in their own industry. Their paper studies the optimal financial policies of firms when the primary motivation of mergers is to reallocate financial resources to firms that may otherwise be inefficiently terminated. In related work, Erel et al. (2015) provide evidence that both foreign and domestic acquisitions ease financial frictions in target firms in a large sample of European acquisitions. They find that the investment levels of the target firms increase significantly following an acquisition. These findings are consistent with our assumption that part of the gains from acquisitions arise out of acquirers relaxing the borrowing constraints of the targets. Other recent papers such as Chari et al. (2010) and Wang and Wang (2015) also document similar financial gains from acquisitions. The paper most similar to ours in this literature is Alquist et al. (2016), who look at fire-sale foreign direct investment in a model where *all* target firms are credit constrained and *all* acquiring firms are unconstrained. In contrast to that paper, we develop here a more general yet tractable framework where constrained (domestic) and unconstrained (foreign) acquisitions can be analyzed simultaneously. We also distinguish between the long-term productivity of firms, and temporary shocks to their productivity or liquidity, and analyze the interplay of these two factors.[9] In addition, our empirical analysis focuses on comparisons between

[8]Our results also speak to a recent empirical literature on this topic that uses disaggregate data to quantify resource misallocation during crises. Oberfield (2013) and Sandleris and Wright (2014) provide evidence from the 1982 Chilean economic crisis and the 2001 Argentine crisis, respectively, of a decline in the efficiency of resource allocation within and across sectors during these crises. These papers do not address resource reallocation through the M&A market.

[9]Alquist et al. (2016) emphasize the industry composition of acquisitions. In their model matches between firms

domestic and foreign acquisitions across crisis and normal times. Our main results, an increase in the degree of control acquired by domestic firms and a convergence of survival rates between domestic and foreign acquisitions, are also novel. More broadly, our paper contributes to the literature on M&As that seeks to explain specific characteristics of acquirer-target matches, for example, Rhodes-Kropf and Robinson (2008), who build and test a model of assortative matching in M&As based on firm valuations.

2 Model

This section presents a simple model of the M&A process where both liquid and illiquid firms can become targets of acquisitions. They can also acquire other firms themselves if they have enough resources. We start in Section 2.1 by describing the set of firms acquired by unconstrained (foreign) firms and contrast it with the set of firms acquired by potentially constrained (domestic) firms. The main comparative static we consider next is an aggregate financial shock to the economy that makes it harder for all domestic firms to borrow, for example, a systemic banking crisis. We show in Section 2.2 that such crises change the composition of acquired firms in terms of their average productivity, and this change works in opposite directions for foreign and domestic acquirers. A corollary of this finding that we later test is that the average acquired share for foreign and domestic acquisitions should also move in opposite directions during financial crises. Section 2.3 then shows that financial crises lead to an aggregate cleansing effect for the domestic economy through the market for corporate control because M&As improve the allocation of resources towards more productive firms. Finally, we extend our model in Section 2.4 to derive an additional hypothesis that financial crises lead to higher subsequent flipping rates for foreign acquirers, but lower flipping rates for domestic acquirers, which we also test

in the same industry are more productive and financial crises lead to more inter-industry acquisitions. Our approach in this paper is more general in that we do not assume any particular industry patterns in the gains from acquisitions. In addition, Alquist et al. (2016) only model the decision of an unconstrained foreign acquiring firm since their focus is on foreign direct investment. Earlier research (see Aguiar and Gopinath, 2005; Acharya et al., 2011) has focussed on the surge of foreign acquisitions and a concurrent decline in domestic acquisitions and portfolio investment during crisis episodes in emerging economies, as well as the relationship between acquisition prices and firm liquidity.

empirically.

2.1 Model Setup

Potential Target Firms

The benchmark model has two periods and a continuum of firms. A firm has ϵA in profits at the end of the first period. The profit margin ϵ is a random variable with an expected value of 1, and is i.i.d. across firms and time.[10] We assume that ϵ is independent of A and constitutes a temporary shock, whereas A can be thought of as baseline (long-term) productivity or firm size.[11] Since a low (high) realization of ϵ means that the firm has fewer (more) internal resources in the first period, we also refer to it as "liquidity". To produce in period two, the firm has to pay an upfront cost proportional to its size, bA, with $b < 1$. Expected output next period is $E(\epsilon')A = A$ and expected profits net of costs are $A(1-b)$ so that the firm prefers production to non-production.

To pay for the upfront cost bA, the firm is limited by a collateral constraint

$$bA \leq \tau\epsilon A, \tag{III.1}$$

where τ measures the degree of credit frictions that is the same across all firms in the economy.[12] In an economy without credit frictions, $\tau = +\infty$, whereas $\tau = 1$ implies financial autarky and firms cannot borrow to pay for the upfront costs. The form of the collateral constraint captures a common prediction from models of limited contract enforcement: The amount of credit is limited by the borrower's wealth (see Bernanke and Gertler, 1989; Kiyotaki and Moore, 1997; Buera et al., 2011, for example). If a firm lacks the liquidity to pay for the upfront cost—that is if $\epsilon < \frac{b}{\tau}$—it

[10] Later on when discussing flipping of acquisitions in a three-period model, we relax the assumption that ϵ is i.i.d. over time, but allow for persistence in form of an AR(1) process.

[11] Following an established literature on heterogeneous firms in international trade that demonstrates the correlation between productivity and firm size, we use the terms "size" and "productivity" interchangeably in what follows.

[12] In an earlier version of this paper, we considered the case where $\tau'(A) > 0$, i.e., smaller firms face tighter credit constraints. Such an assumption would reinforce the mechanism described in this paper, but it is not necessary and we therefore consider the more "conservative" case of $\tau'(A) = 0$.

cannot produce in the second period and the value of the firm is its current profits, ϵA. These firms either exit the market after the first period or become targets of acquisitions. Market exit of this kind can be interpreted as inefficient liquidation of the firm since the firm would always prefer production to non-production in the second period. If a firm is liquid enough, it can produce in the second period, which raises its value by the expected net profit $A(1-b)$.[13] These firms can stay in the market as stand-alone entities, can be targets of acquisitions or can be acquirers themselves. The total value of a potential target firm can then be summarized as

$$V_{tar} = \begin{cases} V_{tar}^{cons} = \epsilon A & \text{if} \quad \epsilon < \frac{b}{\tau} \\ V_{tar}^{uncons} = \epsilon A + A(1-b) = (\epsilon - b + 1)A & \text{if} \quad \epsilon \geq \frac{b}{\tau}. \end{cases}$$

We now discuss the acquisition problem of potential acquirers, starting with financially unconstrained firms.

Financially Unconstrained Acquirers

An unconstrained acquirer is not subject to the borrowing constraint (III.1).[14] It follows that we do not need to keep track of an acquirer's productivity A_{acq} or liquidity ϵ_{acq}. When a firm acquires a target, the target firm produces next period and its productivity increases by a factor ϕ while the acquirer incurs a cost c. The precise form of ϕ and c, which depend on the degree of ownership acquired, are specified and discussed later. For now, we just assume that c has a fixed cost component. The value of an acquired target firm to an unconstrained acquirer is then

$$V_{acq} = (\epsilon - b + \phi)A - c.$$

[13] So there is a discrete jump in the firm's value at $\epsilon = \frac{b}{\tau}$, which is due to the presence of fixed cost. In a model with capital where period two investment costs are determined by productivity, V^d would be a continuous function of ϵ. We abstract from capital as an input for simplicity.

[14] In our model, we think of an unconstrained firm as being from a market that is much more financially developed or that hasn't faced the same financial shock. More generally, our model can also be applied to large domestic firms that face only very loose financing constraints.

An acquisition takes place if the surplus generated by such a match is positive. The surplus is the difference between the value of the acquired firm after and before the acquisition, i.e. $V_{acq} - V_{tar}$, and differs across constrained and unconstrained targets:

$$S = \begin{cases} S^{cons} = (-b + \phi)A - c & \text{if} \quad \epsilon < \frac{b}{\tau} \\ S^{uncons} = (\phi - 1)A - c & \text{if} \quad \epsilon \geq \frac{b}{\tau}. \end{cases}$$

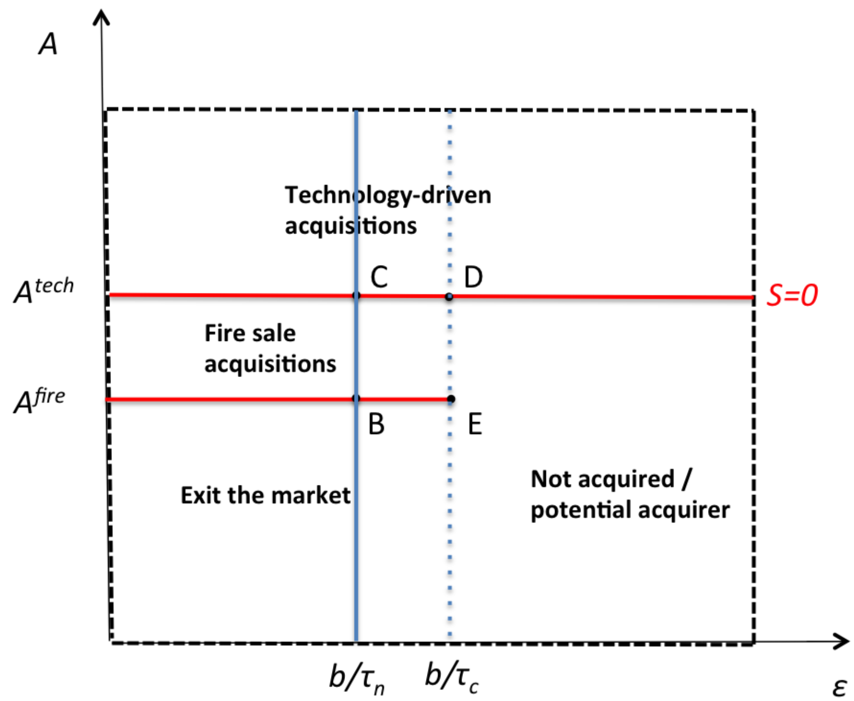


FIGURE III.2: ACQUISITIONS WITH UNCONSTRAINED ACQUIRERS

Note: Combinations of target's size A and liquidity ϵ for which $S^{tech} = 0$ and $S^{fire} = 0$, with A on vertical axis and ϵ on horizonal axis. Areas above the $S = 0$ lines show regions where each type of acquisition generates surplus. Also shows the maximum value for the target's liquidity, $\epsilon = \frac{b}{\tau}$, that makes fire-sale acquisitions profitable during normal and crisis periods. The subscript on the τ indicates (n)ormal or (c)risis periods. See text for more details.

Figure III.2 shows the zero-surplus line $S = 0$ as a function of the target's permanent productivity A and the target firm's liquidity ϵ. We denote the permanent productivity levels that solve $S^{cons} = 0$ and $S^{uncons} = 0$ by A^{fire} and A^{tech}:

$$A^{fire} = \frac{c}{\phi - b}, \qquad A^{tech} = \frac{c}{\phi - 1}, \tag{III.2}$$

with $A^{tech} > A^{fire}$ because $b < 1$.[15] If a target firm of size $A \geq A^{tech}$ is matched with a potential acquirer, an acquisition always takes place because the benefits from the resulting technological synergies always exceed the acquisition costs. This is true irrespective of the target firm's liquidity ϵ and the tightness of the collateral constraint. If a target firm of size $A^{fire} \leq A < A^{tech}$ is matched, technological synergies are not sufficient to make an acquisition profitable. However, if the target firm is constrained (i.e. $\epsilon < \frac{b}{\tau}$), an acquisition generates benefits from both technological synergies and from relaxing the collateral constraint and is therefore profitable. Target firms of size $A < A^{fire}$ never get acquired because the fixed acquisition costs make them unprofitable. We refer to acquisitions of firms with productivity $A \geq A^{tech}$ as "technology-driven" acquisitions and acquisitions of firms with productivity $A^{fire} \leq A < A^{tech}$ as "fire-sale" acquisitions because the latter only take place if the target firm is borrowing constrained.[16] The mass of these fire-sale and technology-driven acquisitions are

$$\begin{aligned} n^{fire*} &\equiv \int_{A^{fire}}^{A^{tech}} \int^{\frac{b}{\tau}} dGdF \\ n^{tech*} &\equiv \int_{A^{tech}} dF. \end{aligned}$$

Figure III.2 also shows the line describing the constraint, $\frac{b}{\tau}$. Firms with A, ϵ combinations to the left of the constraint line cannot pay for the upfront cost and either have to exit the market or become targets of an acquisition. Since τ is independent of A, the constraint line is vertical.

Financially Constrained Acquirers

We now analyze the case of acquirers that are similar to target firms in that they face borrowing constraints, which reduces their ability to perform acquisitions.[17] This means that we need to keep track of the acquirer's size A_{acq} and liquidity ϵ_{acq}. To keep the model tractable and capture

[15] As will be apparent later, these definitions of A^{fire} and A^{tech} are implicit definitions because ϕ and c are functions of the acquired share, which, in turn, is a function of A. See equation (III.6).

[16] The set of technology-driven acquisitions contains target firms that are constrained and would exit the market if they were not acquired. An alternative definition could assign those firms to the set of fire-sale acquisitions.

[17] We call acquirers that are subject to the borrowing constraint (III.1), and thus can potentially hit the constraint if they receive a bad liquidity shock, as "constrained" acquirers even if they are not actually constrained.

the empirical feature that acquirers are invariably much larger than their targets, we impose that $A_{acq} = kA$, with $k \geq 1$. We later calibrate k to the actually observed size difference between domestic acquirers and targets.

In contrast to this proportional-size assumption, we allow acquirers and targets to freely differ in their liquidity. Since the acquirer as well as the target are now financially constrained, we need to consider both of their collateral constraints. The post-acquisition entity's (i.e., the two firms' combined) collateral constraint states that total upfront costs for the target and acquiring firm, including acquisition costs c, $bA + bA_{acq} + c = b(1+k)A + c$, cannot exceed a fraction τ of the total current assets of the two firms: $\epsilon A + \epsilon_{acq} A_{acq} = (\epsilon + \epsilon_{acq} k)A$. This condition can be solved for the target firm's liquidity:

$$\epsilon \;\; \geq \;\; \frac{b(1+k)}{\tau} + \frac{c}{\tau A} - \epsilon_{acq} k \equiv \epsilon^l(A, \epsilon_{acq}, \tau) \tag{III.3}$$

The impact of this joint borrowing constraint on acquisitions is illustrated in Figure III.3. In addition to Figure III.2 for unconstrained acquirers, there is a new downward sloping line, $\epsilon = \epsilon^l(A, \epsilon_{acq}, \tau)$, describing the joint borrowing constraint of the target firm and the acquirer. For a given acquirer's liquidity, ϵ_{acq}, only acquisitions to the right of that line can potentially take place. For more liquid acquirers, the line is shifted to the left and lowers the cut-off value of the target firm's liquidity ϵ. Importantly, the joint borrowing constraint is tighter for smaller firms (illustrated by the finite negative slope) because upfront costs increase less than one-to-one with firm size due to the presence of fixed acquisition costs. Smaller firms therefore need more liquidity to finance an acquisition.

Figure III.3 illustrates that the joint borrowing constraint restrict the mass of both fire-sale and technology-driven acquisitions. More formally, for an acquisition by a constrained firm to take place, the following three conditions have to be met: i) as for unconstrained acquirers, it generates positive surplus, i.e., $A \geq A^{tech}$ for liquid targets, $\epsilon \geq \frac{\tau}{b}$, and $A^{fire} \leq A < A^{tech}$ for illiquid targets, $\epsilon < \frac{\tau}{b}$; ii) the acquiring firm has sufficient collateral so as not to be constrained[18],

[18]We assume that the acquirer has to continue operating its own firm if he wants to acquire another firm.

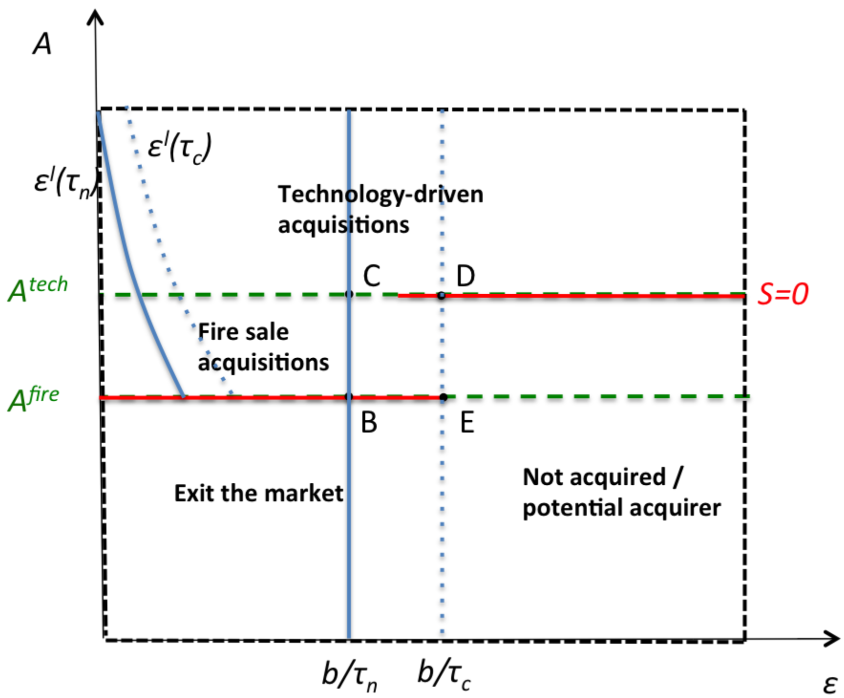


Figure III.3: Acquisitions with Financially Constrained Acquirers

Note: Shows the range of values for the target's current productivity, ϵ, that define fire-sale and technology-driven acquisitions for acquisitions by financially constrained firms during normal and crisis periods. These ranges are $\epsilon^l \leq \epsilon \leq \frac{b}{\tau}$ for fire-sale and $\epsilon \geq \epsilon^l$ for technology-driven acquisitions, with the subscript on the τ indicating (n)ormal or (c)risis periods. See text and notes for Figure III.2 for more details.

i.e., $\epsilon_{acq} \geq \frac{b}{\tau}$; and iii) both firms together have enough current resources to pay for their upfront costs. Based on these conditions, the mass of fire-sale and technology-driven acquisitions are[19]

$$n^{fire} \equiv \int_{A^{fire}}^{A^{tech}} \frac{f(kA)}{f(A)} \int_{\frac{b}{\tau}} \int_{min\left(\frac{b}{\tau},\epsilon^l\right)}^{\frac{b}{\tau}} dGdGdF$$

$$n^{tech} \equiv \int_{A^{tech}}^{\frac{\bar{A}}{k}} \frac{f(kA)}{f(A)} \int_{\frac{b}{\tau}} \int_{\epsilon^l} dGdGdF.$$

Starting from the innermost integral and moving outward, the limits of integration refer to the relevant ranges of the liquidity of the target firm, the liquidity of the acquiring firm, and the size of the target firm, respectively. The fraction $\frac{f(kA)}{f(A)}$, which is less or equal to one for $k \geq 1$ and reasonable size distributions (e.g. the Pareto distribution), is the probability that a target firm

[19]Note that the joint borrowing constraint can potentially lie to the right of the individual borrowing constraint. To ensure that the lower limit of the inner-most integral (over the target firm's ϵ) is always smaller or equal to the upper limit, we set it equal to $min\left(\epsilon^l, \frac{b}{\tau}\right)$ for fire-sale acquisitions.

actually finds a potential acquirer and is proportional to their relative masses.

2.2 Cleansing Effect of Financial Crises in the Market For Corporate Control

In this section, we ask whether financial crises affect the composition, and hence, the average productivity, of acquired firms. In other words, do financial crises lead to a cleansing effect *in* the market for corporate control? We model an aggregate financial shock to the economy as a decrease in τ from τ_n to τ_c, so that a higher level of ϵ is needed to be able to pay the upfront cost from $\frac{b}{\tau_n}$ to $\frac{b}{\tau_c}$. Then, we define the cleansing effect in the market for corporate control as follows:

Definition 2. ***Cleansing effect in the market for corporate control***

A financial crisis leads to a cleansing effect in the market for corporate control if the average long-term productivity $\hat{A}_{in}$ of acquisitions increases, i.e., if $\tau_c < \tau_n$ then $\hat{A}_{in,c} > \hat{A}_{in,n}$, and to a sullying effect if the average long-term productivity decreases, i.e., if $\tau_c < \tau_n$ then $\hat{A}_{in,c} < \hat{A}_{in,n}$.

This definition only focuses on firms' long-term productivity A, but ignores temporary liquidity shocks ϵ or technological synergies that result from acquisitions. We abstract from short-run productivity fluctuations, but rather ask whether financial crises affect the composition of acquired firms in terms of their fundamental productivity of acquired firms.

Cleansing Effect for Acquisitions by Unconstrained Firms

We start by defining the average long-term productivity $\hat{A}^*_{in}$ for unconstrained acquirers (the superscript * indicates *unconstrained* acquirers). Let F and G denote the distributions associated with the target firm's long-term productivity A and liquidity ϵ. Then, using Bayes' formula, we can write the average productivity as the expected productivity conditional on an acquisition taking place:[20]

$$\hat{A}^*_{in} = \frac{\int_{A^{fire}}^{A^{tech}} \int^{\frac{b}{\tau}} AdGdF + \int_{A^{tech}} AdF}{\int_{A^{fire}}^{A^{tech}} \int^{\frac{b}{\tau}} dGdF + \int_{A^{tech}} dF}.$$

We define $A^{fire^*} \equiv \int_{A^{fire}}^{A^{tech}} \int^{\frac{b}{\tau}} AdGdF$ and $A^{tech^*} \equiv \int_{A^{tech}} AdF$ as the sum of productivities in fire-sale and technology-driven acquisitions. Then, the average productivity of acquired firms in each type of acquisitions, $\hat{A}^{fire^*}$ and $\hat{A}^{tech^*}$, can be written as:

$$\hat{A}^{fire^*} = \frac{A^{fire^*}}{n^{fire^*}} \qquad \hat{A}^{tech^*} = \frac{A^{tech^*}}{n^{tech^*}}.$$

As discussed, technology-driven acquisitions target more productive firms than fire-sale acquisitions, so that $\hat{A}^{tech^*} > \hat{A}^{fire^*}$.

The average productivity of unconstrained acquisitions overall, $\hat{A}^*_{in}$, can be conveniently expressed as the weighted sum of these average productivites, with the weights being the share of these two types of acquisitions in total unconstrained acquisitions:

$$\hat{A}^*_{in} = \omega^*_{in} \hat{A}^{fire^*} + (1 - \omega^*_{in}) \hat{A}^{tech^*}, \tag{III.4}$$

where $\omega^*_{in} = \frac{n^{fire^*}}{n^{fire^*} + n^{tech^*}}$. Taking the derivative with respect to the borrowing constraint parameter then leads to the following proposition:

Proposition 1. ***Sullying effect of crises on acquisitions by unconstrained firms***
Financial crises have a sullying effect on acquisitions by unconstrained firms in the sense that they lead to a lower average productivity of acquired firms, i.e., if $\tau_c < \tau_n$ then $\hat{A}^*_{in,c} < \hat{A}^*_{in,n}$.

Proof: See Technical Appendix.

The decrease in the average productivity purely comes from a change in the composition

[20] We omit the bounds on the random variables A and ϵ to avoid cluttering integrals and diagrams.

of acquisitions (extensive margin) rather than any changes in the average productivities of fire-sale acquisitions and technology-driven acquisitions (intensive margin).[21] The shock increases the share ω_{in}^* of fire-sale acquisitions (region $\overline{BCDE}$ in Figure III.2) as a larger proportion of potential target firms find themselves unable to raise enough external debt financing to cover the upfront cost of operating in the second period, and thus face liquidation.

Cleansing Effect for Acquisitions by Constrained Firms

We write the average productivity of constrained acquisitions as the weighted sum of the average productivities of fire-sale acquisitions and technology-driven acquisitions, similar to equation (Appendix J):

$$\hat{A}_{in} = \omega_{in}\hat{A}^{fire} + (1-\omega_{in})\hat{A}^{tech}$$

where $\hat{A}^{fire}$ and $\hat{A}^{tech}$ denote the average productivities for fire-sale and technology-driven acquisitions by constrained acquirers:

$$\hat{A}^{fire} = \frac{A^{fire}}{n^{fire}} = \frac{\int_{A^{fire}}^{A^{tech}} \frac{f(kA)}{f(A)} \int_{\frac{b}{\tau}} \int_{min\left(\frac{b}{\tau},\epsilon^l\right)}^{\frac{b}{\tau}} AdGdGdF}{\int_{A^{fire}}^{A^{tech}} \frac{f(kA)}{f(A)} \int_{\frac{b}{\tau}} \int_{min\left(\frac{b}{\tau},\epsilon^l\right)}^{\frac{b}{\tau}} dGdGdF}$$

$$\hat{A}^{tech} = \frac{A^{tech}}{n^{tech}} = \frac{\int_{A^{tech}}^{\frac{\bar{A}}{k}} \frac{f(kA)}{f(A)} \int_{\frac{b}{\tau}} \int_{\epsilon^l} AdGdGdF}{\int_{A^{tech}}^{\frac{\bar{A}}{k}} \frac{f(kA)}{f(A)} \int_{\frac{b}{\tau}} \int_{\epsilon^l} dGdGdF}$$

and $\omega_{in} = \frac{n^{fire}}{n^{fire}+n^{tech}}$. This expression is useful for analyzing the effect of changes in τ, and hence the effect of financial shocks, on $\hat{A}_{in}$. Its partial derivative with respect to τ is

$$\frac{\partial \hat{A}_{in}}{\partial \tau} = \frac{\partial \omega_{in}}{\partial \tau}\left(\hat{A}^{fire} - \hat{A}^{tech}\right) + \omega_{in}\frac{\partial \hat{A}^{fire}}{\partial \tau} + (1-\omega_{in})\frac{\partial \hat{A}^{tech}}{\partial \tau}. \tag{III.5}$$

[21] The absence of an intensive margin is the result of a borrowing constraint that is constant across firms. If borrowing constraints are tighter for smaller firms, the intensive margin will contribute to the decrease in the average productivity.

A negative financial shock leads to two adjustments: First, as for unconstrained acquirers, it shifts the target's borrowing constraint line, $\epsilon = \frac{b}{\tau}$, to the right. This has the effect of increasing the mass of fire-sale acquisitions $\left(\frac{\partial \omega_{in}}{\partial \tau}\right) > 0$, which lowers the average productivity of acquisitions because fire-sale acquisitions have a lower productivity than technology-driven acquisitions $\left(\hat{A}^{fire} < \hat{A}^{tech}\right)$. Second, a financial shock also tightens the joint borrowing constraint, shifting the $\epsilon = \epsilon^{l}(A, \epsilon_{acq}, \tau)$ line to the right (see Figure III.3) and making it harder for firms to acquire targets. This second force is only present for constrained acquirers and tends to work in the opposite direction of the first force. Its first effect is to reduce the increase in the share of fire-sale acquisitions because some fire-sale acquisitions cannot take place as acquirers find themselves unable to raise sufficient funds. This dampens the rise in $\frac{\partial \omega_{in}}{\partial \tau}$.

There is a second, more subtle effect that raises the average productivity of both groups of fire-sale and technology-driven acquisitions (the last two terms in equation (III.5)). Key for understanding this intensive margin effect is the interaction of fixed costs and borrowing constraints. The presence of fixed costs renders acquisitions among small firms unprofitable. This was also the reason why foreign, unconstrained firms do not acquire any small firms with $A < A^{fire}$. Adding borrowing constraints for the acquiring firm skews the distribution of acquired firms even further towards bigger firms. The reason is as follows: Firms have to pre-finance their upfront costs. These upfront costs increase less than one-to-one with firm size due to the presence of fixed acquisition costs, so that smaller firms need relatively more liquidity to finance an acquisition. Some of those smaller firms might not have enough liquidity and cannot acquire the target firm, even though it would be profitable. This means that fixed costs do not only render acquisitions among small firms unprofitable, but they also make some profitable acquisitions *infeasible*. This last effect results from the interaction of fixed costs and borrowing constraints and is only present for constrained acquirers. Importantly, a financial crisis tightens borrowing constraints and makes more and more acquisitions infeasible, particularly among small firms. That is, in the presence of fixed costs, tighter borrowing constraints have a more negative impact on smaller firms than larger firms. Technically, this can be seen from taking the second derivative of the joint borrowing constraint (III.3) with respect to τ and A. In Figure III.3, this effect is illustrated through a stronger shift of the joint borrowing constraint for smaller values of A.

These two channels—the dampening of the extensive margin and the movement of the intensive margin—tend to raise the average productivity $\hat{A}_{in}$ associated with constrained acquisitions and may counteract the decline in average productivities caused by the increase in the fire-sale target pool. Whether that happens is a quantitative question that we settle by numerical simulations. In the simulations that we present below, we find that under certain plausible conditions, the second set of effects dominates the effect of an increase in the fire-sale target pool, and as a result, the average productivity by constrained acquiring firms goes up in the aftermath of an aggregate financial shock. This is a central insight of our analysis: The "quality" of acquisitions completed by constrained acquirers improves during financial crises because more of the matches taking place are between firms with higher values of A, the technology-related fundamental. If the financially constrained firms be interpreted as domestic firms, then acquisitions completed by domestic firms during financial crisis should be based more on fundamentals, in contrast to unconstrained acquirers (foreign firms). This is, there is a "cleansing effect" in the market for corporate control, whereby large aggregate financial shocks lead to a higher average quality of completed acquisitions among the group of domestic acquiring firms.

Before showing quantitative results for the cleansing effect in the market for corporate control, we discuss how financial crises affect the average acquired share of acquisitions. This effect is strongly related to the cleansing effect. The acquired share is empirically easy to measure, which allows us to test our model's implications.

Acquired Share and Aggregate Financial Shocks

When a firm acquires a target, the productivity of the target increases by a factor ϕ, which is both increasing and strictly concave in the acquired share α.[22] But the frictions associated with

[22] The first part of the assumption is meant to capture the gains arising from technological synergies between the two firms. Thus there are no value-destroying acquisitions (see Moeller et al., 2005) in our setup. The second part of the assumption is meant to capture the role of ownership in mitigating hold-up problems arising from incomplete contracts or transaction costs. Higher ownership by the acquiring firm is also more likely to incentivize

the acquisition process necessitate a cost $c(\alpha)$ with $c(0) > 0$, $c' > 0$ and $c'' \geq 0$.[23] The precise form of the marginal cost curve of acquiring additional ownership is not critical for our results.

For simplicity, we assume that the two parties set up a contract that aligns their interests. As a result, the acquired share is chosen by the acquiring firm to maximize total surplus:[24]

$$\phi'(\alpha)A = c'(\alpha). \tag{III.6}$$

This condition simply states that the marginal benefit of an increase in α, $\phi'(\alpha)A$, has to equal the marginal cost of an increase in α, $c'(\alpha)$. We can think of the optimal α defined by this first order condition as a function $\alpha(A)$.[25] Under our assumptions about the derivatives of ϕ and c, it is easy to show that $\alpha' > 0$.[26] Ceteris paribus, smaller stakes are associated with lower productivity. In this sense, there is a strong, monotonic relationship between the fraction of a target firm acquired and the "quality" of targets acquired, measured by the productivity of the target firm.

This insight together with our results that the average productivity of acquisitions by unconstrained acquirers goes down during crises leads to the following proposition:[27]

Proposition 2. ***Smaller acquired shares for unconstrained firms during crises***

Unconstrained firms acquire on average smaller shares during financial crises, i.e., if $\tau_c < \tau_n$ then $\hat{\alpha}^*_c < \hat{\alpha}^*_n$.

the introduction of better management practices and enable closer monitoring of existing processes.

[23]This is meant to capture the idea that acquiring higher stakes might involve a greater degree of pre-acquisition screening and higher administrative or legal costs. The assumption $c'' \geq 0$ can be relaxed if ϕ is sufficiently concave (see footnote 26).

[24]This is done to simplify the algebra. Alternatives, such as the acquirer maximizing her share of surplus αS, would add complexity without adding insight into the main effect the model is meant to highlight. See Alquist et al. (2015) for a more complete analysis of the contracting problem in an acquisition.

[25]Practically, we restrict α to be less or equal to 1.

[26] This condition holds as long as $\frac{c''(\alpha)}{c'(\alpha)} > \frac{\phi''(\alpha)}{\phi'(\alpha)}$, which is satisfied if c is strictly convex and a is strictly concave. One can read the inequality condition as saying that c has to be "less concave" / "more convex" than ϕ for all possible α.

[27]This result is similar to Alquist et al. (2016). They emphasize the role of within-industry synergies in driving a similar result for foreign acquisitions. They do not consider the decision problem of a domestic acquiring firm.

Proof: See Technical Appendix.

As our previous discussion on constrained acquirers suggest, the movement of the joint borrowing constraint might overturn this result. In the next section, we calibrate our model to show that under certain plausible conditions, financially constrained firms indeed acquire on average larger shares during financial crises.

Calibrating and Simulating the Model

We simulate the model to analyze the reaction of the average productivity and average acquired share to a tightening of the collateral constraint. We first have to choose functional forms and parameters. Some of these parameters are chosen to match certain features of the data on emerging market acquisitions from the years 1990-2007, which are described later in the empirical section. For the purpose of the calibration, unconstrained and constrained acquiring firms are identified with foreign and domestic acquirers respectively. This seems a reasonable assumption because the majority of foreign acquiring firms in our sample were from countries with more well-developed financial markets, not other EMEs.[28]

For the size parameter A we choose a Pareto distribution with probability density function $f(A) = \lambda A^{-\lambda-1}$ for $A \geq 1$. In accordance with the literature on firm size distributions, we select a value of the shape parameter close, but above 1: 1.01.[29] There is less guidance for the distribution of the temporary shock ϵ. We have experimented with uniform, normal, log-normal and beta distributions and different standard deviations. Our qualitative results are robust to these distributions and reasonable standard distributions. Our results presented in this section assume a log-normal distribution with a standard distribution of 0.43.[30]

The cost function and spillover function jointly determine the distribution of the acquired

[28]This is documented in Alquist et al. (2015) using indices of financial development such as private credit/GDP and bond market capitalization/GDP ratios.

[29]See e.g. Di Giovanni et al. (2011) for estimates of λ.

[30]We choose the log-normal distribution because in a later section on possible resales of acquisitions, we assume that $\log(\epsilon)$ follows an AR(1) process. If the errors of this AR(1) process are Gaussian, then $\log(\epsilon_t)$ is normally distributed as $t \to \infty$.

share. We assume their forms to be:

$$c = \gamma_0 + \alpha$$
$$\phi = 1 + \alpha^{\psi}$$

The cost of an acquisition consists of a fixed cost γ_0 and a variable cost that is linearly increasing in the acquired share α. The value of the fixed cost strongly affects the average acquired share. As the fixed cost increases, small acquisitions become unprofitable and the average share increases. The form for the spillover function ensures that productivity spillovers are non-negative and are increasing in α. As the elasticity ψ increases, spillover more strongly increase in α, making larger acquisitions more profitable. Since we have to restrict α to be between 0 and 1, an increase in ψ raises the share of full acquisitions. We choose γ_0 and ψ to match as best as possible both the average acquired share and the fraction of full acquisitions that we observe in the data. Table III.1 compares acquired shares in the data and the model. We cannot perfectly match the two moments: In the data, the fraction of full acquisitions is somewhat larger than in the model. At the same time, the average acquired share is smaller. The reason for the discrepancy is that the model does not feature any small scale acquisitions with shares of less than 30%, which can be observed in the data. However, the fit is fairly good for our very parsimonious model. In both the data and the model roughly 75% of all acquisitions lead to shares with 50% or more.

We calibrate the parameter k to the observed size difference of domestic acquirers and their target. We measure a firm's size as the book value of their total assets. Our dataset contains 1,518 domestic acquisitions for which total assets of both the acquirer and the target are available. The resulting ratio of the average acquirer's total assets to the average target's total assets is 3.2 across all years and countries. We therefore set $k = 3.2$.

Finally, we choose the fixed cost parameter to be $b = 0.9$. This implies that expected profits are 10% of a firm's size.

We now simulate a tightening of the collateral constraint from $\tau = 1.33$ to $\tau = 1$, translat-

Table III.1: Acquired Share in Data and Model

	$< 50\%$	$50-60\%$	$60-70\%$	$70-80\%$	$80-90\%$	$90-100\%$	100%	$\hat{\alpha}$
Data	28.7%	8.8%	5.9%	2.5%	3.7%	2.7%	47.8%	70.1%
Model	23.0%	10.0%	7.6%	6.0%	4.8%	4.0%	44.5%	76.9%

Notes: The table reports average acquired shares for the total of domestic and foreign acquisitions in the data and the model. Model parameters are explained in the text. For this table, we set $\tau = 1.17$.

ing into a 25% drop of a firm's maximum leverage ratio.[31] This means that firms loose complete access to financial markets, so that they can only pay for the fixed cost b if their current productivity is high enough, i.e. $\epsilon \geq b$. We analyze the effect of this tightening on both the average productivity of acquisitions and the average acquired share.

Figure III.4(a) shows how the average productivity of both unconstrained and constrained acquirers adjusts to a steady decline in τ from 1.33 to 1. The average productivity is standardized to 100 in normal times ($\tau = 1.33$). As credit constraints tighten, we observe—in line with Proposition 1—that the average productivity for foreign (unconstrained) acquisitions goes down by 2.5 percent, whereas it increases by 10 percent for domestic (constrained) acquisitions.[32] This suggests a fairly strong cleansing effect for domestic acquisitions despite the increase in the pool of low-productivity, distressed targets. Figure III.4(b) decompose this overall change in the average productivity into three components (where a prime $'$ denotes the value after the change)

$$\Delta \hat{A} = \underbrace{\left(\hat{A}^{fire} - \hat{A}^{tech}\right)\Delta\omega}_{Ext} + \underbrace{\omega'\Delta\hat{A}^{fire}}_{Int^{fire}} + \underbrace{(1-\omega')\Delta\hat{A}^{tech}}_{Int^{tech}} \tag{III.7}$$

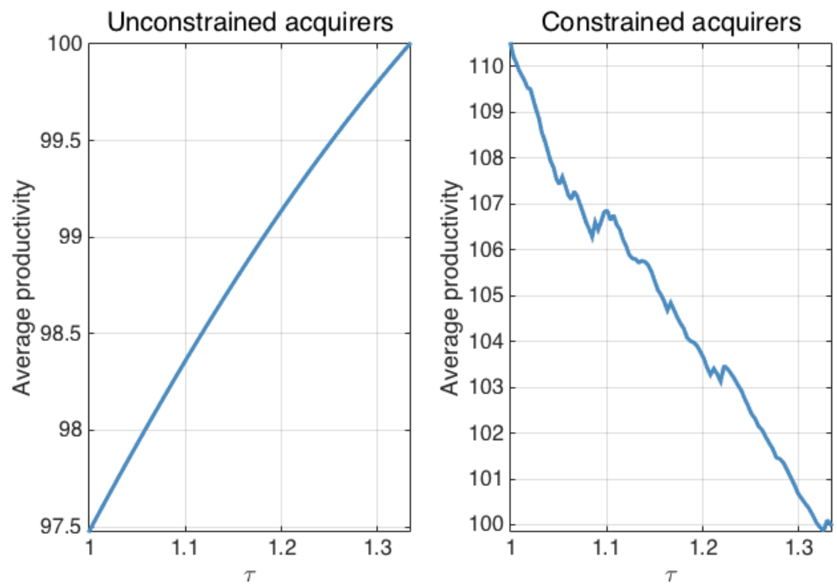
This decomposition follows equation (III.5). The extensive margin captures the composition effect of a change in the average productivity of fire-sale and technology-driven acquisitions. The

[31] The leverage ratio typically refers to total liabilities over total assets. We deviate from this definition by calling the ratio of total liabilities to total equity the leverage ratio. Also, in our two-period model, all liabilities are current.

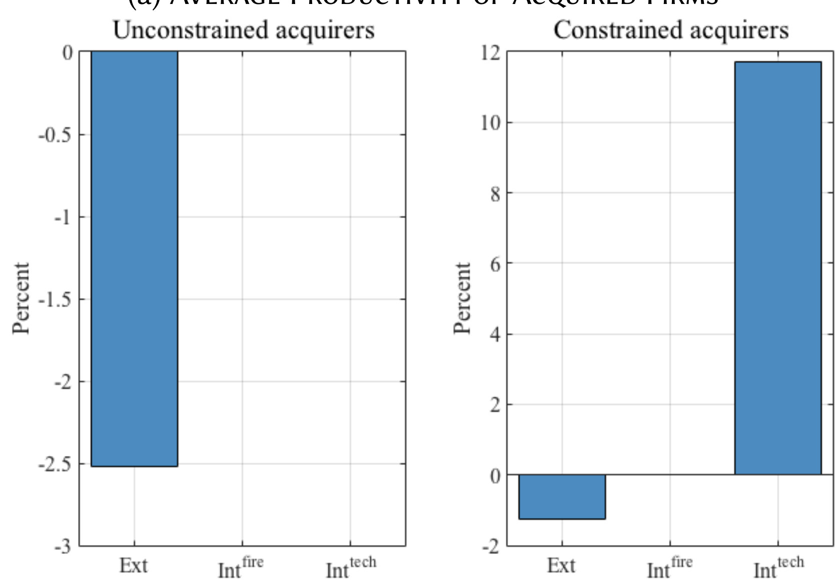
[32] The non-monotonic behavior for the average productivity of constrained acquisitions is a result of the distribution for A. The Pareto distribution has no mean for shape parameters smaller than 1. We chose 1.01 for our simulations are therefore very close to this threshold. We randomly draw 5'000'000 values for A from this distribution, but only 70'000 of these 'firms' get acquired by a domestic firm. This number is too small to average out the randomness introduced by our simulation.

two intensive margins refer to changes in the average productivity of the two types of acquisitions. Figure III.4(b) shows the result of this decomposition for a change in τ from 1.33 to 1, for both unconstrained and constrained acquisitions. As discussed before, the fall in the average productivity for unconstrained acquisitions is completely driven by a composition change. For domestic acquisitions, this composition effect is weaker and is dominated by an increase in the average productivity for technology-driven acquisitions. This result supports our intuition that during financial crises only the best domestic acquiring firms – those with higher productivity and liquidity – remain in the market for corporate control. The increase in the share of fire-sale acquisitions is less pronounced for domestic acquirers because the acquirers themselves face tighter borrowing constraints. Low-quality matches therefore become less profitable.

Finally, Figure III.5 shows that these different responses to financial crises by foreign and domestic acquisitions are also mirrored in their average acquired shares. At $\tau = 1.33$ the share of both unconstrained and constrained acquirers is somewhat close to each other at 73.8 and 75.4 percent, respectively. As credit constraints tighten, the average share declines for unconstrained acquisitions by more than one percentage point, whereas it increases by a similar amount for constrained acquisitions.



(a) Average Productivity of Acquired Firms



(b) Decomposition of a Change in the Average Productivity

Figure III.4: Cleansing Effect in the Market for Corporate Control

Note: Figure (a) shows the simulated average productivity of firms acquired by unconstrained firms (left panel) and constrained firms (right panel) as a function of τ (collateral constraint parameter). A financial crisis is modeled as a decrease of τ. Figure (b) decomposes the percentage change from $\tau = 1.33$ to $\tau = 1$ into a composition change, the extensive margin, and a change in the average productivity of both fire-sale acquisitions and technology acquisitions (see Equation (III.7)). See text for more details on the calibration.

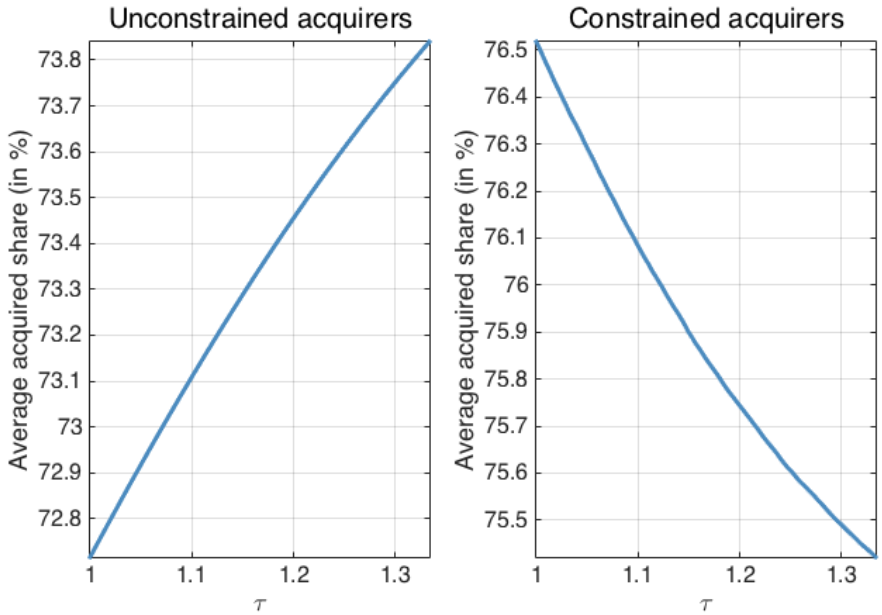


FIGURE III.5: AVERAGE ACQUIRED SHARE

Note: Simulated average acquired share as a function of τ (collateral constraint parameter) for unconstrained acquirers (left panel) and constrained acquirers (right panel).

2.3 Aggregate Cleansing Effects of Financial Crises

In this section, we show that the presence of acquirers alters standard predictions on the aggregate cleansing effect of a negative financial shock. Foreign acquisitions amplify the cleansing effect because acquirers save high-productivity firms and let low-productivity firms go bankrupt. This is also true for domestic acquisitions, but the presence of financial constraints for domestic acquirers render this cleansing effect negligible.

We start by defining the aggregate cleansing effect that works *through* the market for corporate control:

Definition 3. ***Cleansing effect through the market for corporate control***

A financial crisis leads to a cleansing effect through the market for corporate control if the average long-term productivity $\hat{A}_{thru}$ *of surviving domestic firms increases, i.e., if* $\tau_c < \tau_n$ *then* $\hat{A}_{thru,c} > \hat{A}_{thru,n}$*, and a sullying effect if the average long-term productivity decreases, i.e., if* $\tau_c < \tau_n$ *then* $\hat{A}_{thru,c} < \hat{A}_{thru,n}$.

We look at three types of economies to evaluate the relevance of acquirers for the aggregate cleansing effect. We start with a version of our model without any acquirers. Then, we allow for either unconstrained or constrained acquirers.

Aggregate Cleansing Effect Without a Market for Corporate Control

The average productivity $\hat{A}_{thru}$ refers to all domestic firms that decide to produce in the next period. In our simple model without any acquirers, only firms that satisfy the borrowing constraint $\epsilon \geq \frac{b}{\tau}$ can pay for the fixed cost of production. All other firms exit the market.

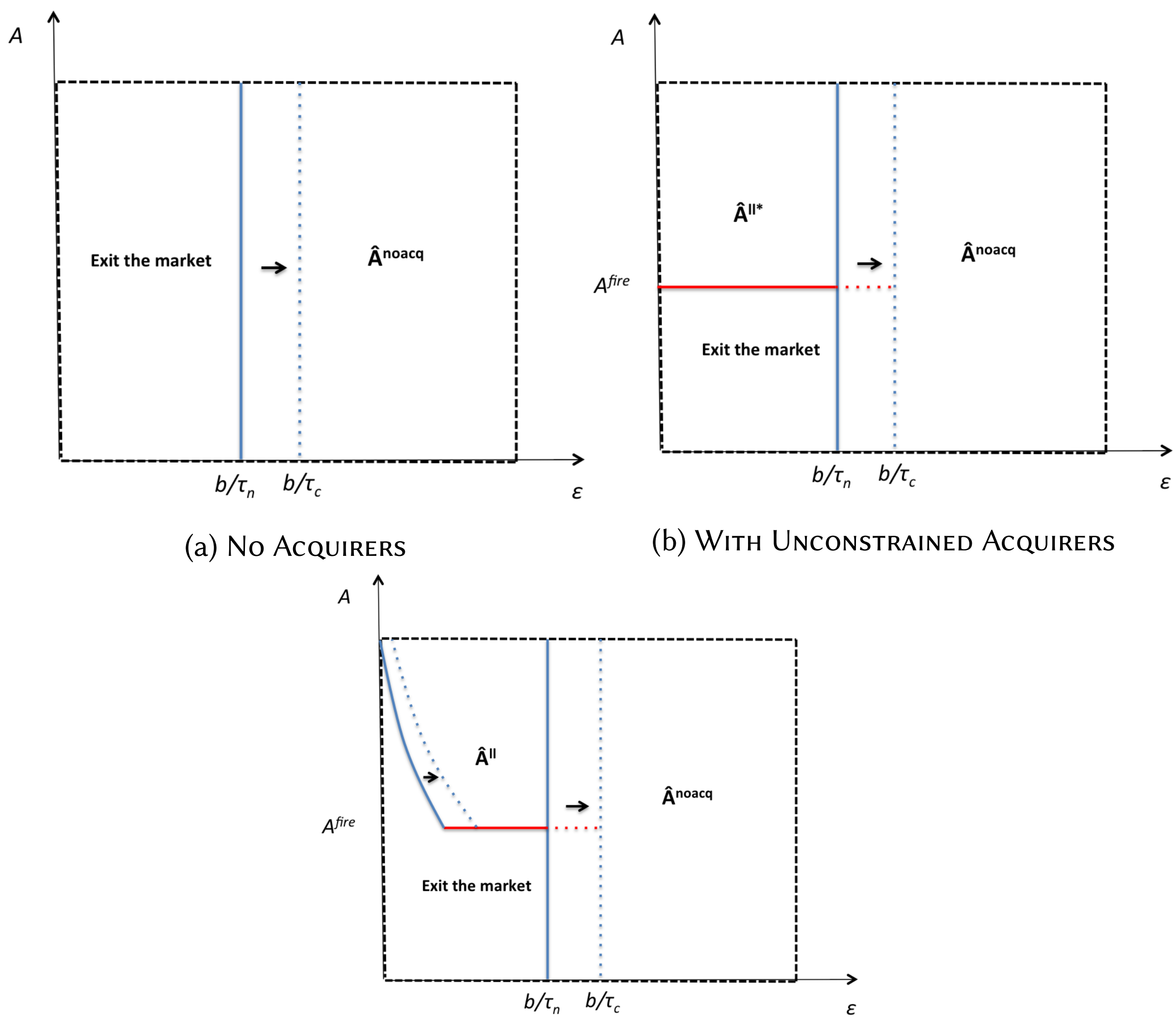
$$\hat{A}^{noacq}_{thru} = \frac{\int \int_{\frac{b}{\tau}} AdGdF}{\int \int_{\frac{b}{\tau}} dGdF} \equiv \frac{A^{noacq}}{n^{noacq}}.$$

Figure III.6(a) illustrates the set of firms that exit or stay in the market. A financial crisis shifts the borrowing constraint to the right, which raises the number of firms that exit the market, but, as the following proposition states, does not affect the average productivity of producing firms.

Proposition 3. ***No cleansing effect on domestic firms in absence of acquisitions***
In a model without any acquirers, financial crises do neither lead to a cleansing effect nor a sullying effect through the market for corporate control, i.e., if $\tau_c < \tau_n$ *then* $\hat{A}^{noacq}_{thru,c} = \hat{A}^{noacq}_{thru,n}$.

Proof: See Technical Appendix.

Intuitively, our model lacks a cleansing effect for two reasons. First, the borrowing constraint is independent of a firm's productivity A. As a result, both low-productivity and high-productivity firms are equally affected by financial crises. This is illustrated by the vertical borrowing constraint in Figure III.6(a). Second, we assume that a firm's liquidity ϵ is uncorrelated with its productivity A. This assumption is in contrast to the dynamic model in Osotimehin and Pappadà (forthcoming) that features a negative cleansing effect of financial crises. In their model, high-productivity firms have a stronger need for borrowing to finance their investment



(a) No Acquirers

(b) With Unconstrained Acquirers

(c) With Constrained Acquirers

Figure III.6: Cleansing Effect of Liquidity Crises

Note: Figure illustrates the change in the average productivity for producing domestic firms in a model without any acquirers (a), with only unconstrained acquirers (b), and with only constrained acquirers (c). Each plot shows which domestic firms (characterized by a combination of A and ϵ) exit or stay in the market. $\hat{A}^{noacq}$, $\hat{A}^{ll^*}$ and $\hat{A}^{ll}$ denote average productivity levels of the domestic firms with the respective combinations of A and ϵ. See text for more details.

and will therefore suffer more from tight credit markets than low-productivity firms. We abstract from this mechanism to focus on how the presence of acquirers alters the predictions of the cleansing effect.[33] Starting from a baseline of a zero cleansing effect in the absence of a

[33] It would be straightforward to extend the model to incorporate both of these features. We could have a borrowing constraint that depends on firm size. If smaller firms (which have lower long-run productivity in our static model) face tighter constraints, then a negative financial shock will lead to a positive cleansing effect as these firms exit. An earlier version of this paper considered this case. Regarding the correlation of ϵ and A: A positive (or nega-

market for corporate control, we now introduce acquirers.

Aggregate Cleansing Effect with Unconstrained Acquirers Only

Allowing for unconstrained acquirers alters the predictions on the cleansing effect. Now, some of the firms that cannot pay for the upfront fixed cost get acquired and stay in the market. As discussed, unconstrained firms will acquire all low liquidity firms $\left(\epsilon < \frac{\tau}{b}\right)$ with productivity $A \geq A^{fire}$. That means in addition to all domestic firms with sufficient liquidity, also firms with productivity $A \geq A^{fire}$ stay in the market. Denote the average productivity of these latter, (l)ow (l)iquidity firms by $\hat{A}^{ll*}$. Figure III.6(b) illustrates these two sets of surviving firms. Then, the average productivity of producing domestic firms is a weighted average of these two sets of surviving firms:

$$\hat{A}^{*}_{thru} = \omega^{*}_{thru}\hat{A}^{ll*} + (1-\omega^{*}_{thru})\hat{A}^{noacq},$$

where $\hat{A}^{ll*}$ denotes the average productivity of acquired firms with low liquidity $\left(\epsilon < \frac{\tau}{b}\right)$:

$$\hat{A}^{ll*} = \frac{A^{ll*}}{n^{ll*}} = \frac{\int_{A^{fire}} \int^{\frac{b}{\tau}} AdGdF}{\int_{A^{fire}} \int^{\frac{b}{\tau}} dGdF}$$

and $\omega^{*}_{thru} = \frac{n^{ll*}}{n^{ll*}+n^{noacq}}$. As Figure III.6(b) suggests, a financial crisis forces more firm exits, but only of firms with very low productivity. A financial crisis therefore raises the share of acquired, low-liquidity firms, ω^{*}_{thru}. This observation leads to the following proposition.

Proposition 4. ***Cleansing effect on domestic firms with unconstrained acquirers***

In a model with only unconstrained acquirers, financial crises lead to a cleansing effect through the market for corporate control, i.e., if $\tau_c < \tau_n$ then $\hat{A}^{*}_{thru,c} > \hat{A}^{*}_{thru,n}$.

tive) correlation between ϵ and A would mean that the bankrupt firms would also be the less (or more) productive ones, which would lead to a positive (or negative) cleansing effect. Abandoning the assumption of the independence of ϵ and A, however, would come at the cost of sacrificing some of our earlier analytical results.

Proof: See Technical Appendix.

The intuition for the positive cleansing effect is that unconstrained acquirers only save high-productivity firms from exiting the market. Even though financial crises hit all domestic firms equally, only the "fittest", high-productivity firms (with $A > A^{fire}$) survive by getting acquired, whereas the low-productivity firms exit the market. The average productivity of these low-liquidity, acquired firms is therefore relatively high, so that, as their share goes up, total average productivity rises. As we have seen with changes in the average productivity of unconstrained acquisitions, all the movements in the average productivity level of surviving, constrained firms, are driven by the extensive margin, i.e. changes in ω^*_{thru} as opposed to changes in $\hat{A}^{ll*}$ or $\hat{A}^{noacq}$

This result that the average productivity of producing firms goes *up* during financial crises might seem at odds with our finding that, at the same time, the average productivity of unconstrained acquisitions goes *down*. To see that these two results are actually consistent with each other, one must keep in mind that they concern two different groups of firms. During financial crises, the average productivity of acquired firms goes down because more low-productivity firms get acquired (sullying effect in the market for corporate control). But as more firms get acquired, the average productivity of the overall population of producing firms goes up because acquired firms are, on average, more productive than the population of producing firms (cleansing effect through the market for corporate control).

Aggregate Cleansing Effect with Constrained Acquirers Only

In a model with constrained acquirers not all low-liquidity firms with $A \geq A^{fire}$ get acquired. Acquisitions only take place if the combined borrowing constraint $\epsilon \geq \epsilon^l$ is satisfied. Figure III.6(c) shows that, compared to the case with unconstrained acquirers, the joint borrowing constraint restricts the set of surviving firms to more productive or more liquid firms. As before, the average productivity of producing domestic firms is a weighted average of two sets of surviving firms:

$$\hat{A}_{thru} = \omega_{thru}\hat{A}^{ll} + (1-\omega_{thru})\hat{A}^{noacq},$$

where $\hat{A}^{ll}$ denotes the average productivity of acquired firms with low liquidity $\left(\epsilon < \frac{\tau}{b}\right)$:

$$\hat{A}^{ll} = \frac{A^{ll}}{n^{ll}} = \frac{\int_{A^{fire}} \frac{f(kA)}{f(A)} \int_{\frac{b}{\tau}}^{\bar{\epsilon}} \int_{min\left(\frac{b}{\tau},\epsilon^{l}\right)}^{\frac{b}{\tau}} AdGdGdF}{\int_{A^{fire}} \frac{f(kA)}{f(A)} \int_{\frac{b}{\tau}}^{\bar{\epsilon}} \int_{min\left(\frac{b}{\tau},\epsilon^{l}\right)}^{\frac{b}{\tau}} dGdGdF}$$

and $\omega_{thru} = \frac{n^{ll}}{n^{ll}+n^{noacq}}$. Taking the partial derivative yields

$$\frac{\partial \hat{A}_{thru}}{\partial \tau} = \frac{\partial \omega_{thru}}{\partial \tau}\left(\hat{A}^{ll} - \hat{A}^{noacq}\right) + \frac{\partial \hat{A}^{ll}}{\partial \tau}\omega_{thru}.$$

For unconstrained acquirers, the cleansing effect was driven by an increase in the share of domestic firms with insufficient liquidity, ω^{*}_{thru}. As illustrated in Figure III.6(c), this extensive margin is dampened now because constrained acquirers find themselves unable to save low-liquidity firms when borrowing constraints tighten ($\epsilon = \epsilon^{l}$ shifts right): That is, we expect ω_{thru} to be less sensitive to changes in τ than ω^{*}_{thru}, and hence, a dampened cleansing effect. That being said, the equation has a second term that reinforces the cleansing effect. It relates to changes in the average productivity of firms with liquidity problems, $\hat{A}^{ll}$. Since acquisitions among smaller firms suffer more from tighter borrowing constraints due to the fixed cost, we expect relatively more acquisitions among firms with high productivity. This raises the average productivity of surviving firms during crises and reinforces the cleansing effect. To quantify these two opposing channels, we now simulate our model economy.

Figure III.7 shows that the cleansing effect of financial crises in a model with only constrained acquisitions is relatively small compared to the cleansing effect of unconstrained acquisitions. The model with constrained acquirers has a relatively small share of firms with liquidity problems that are saved through acquisitions (low ω_{thru}) because constrained acquirers themselves

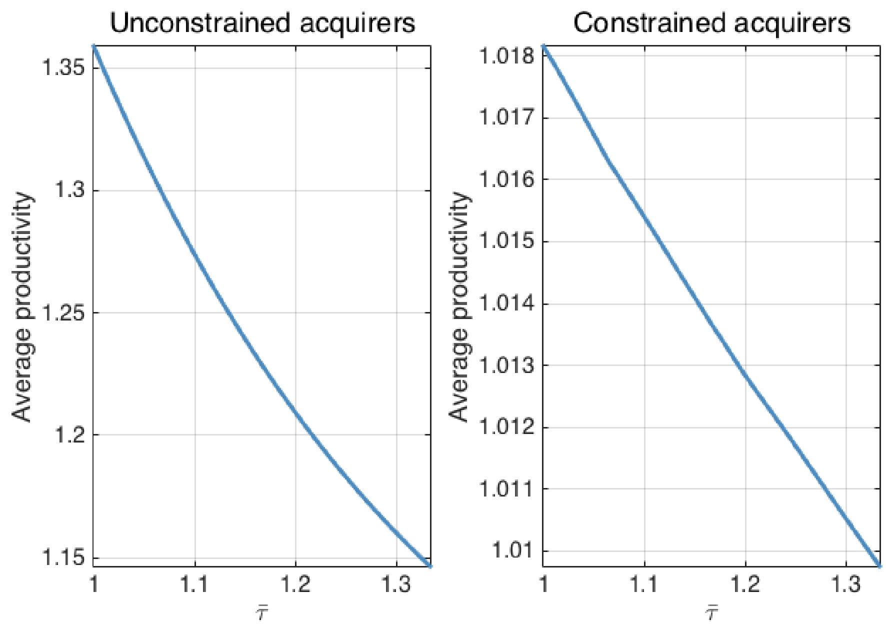


FIGURE III.7: AVERAGE PRODUCTIVITY OF PRODUCING, DOMESTIC FIRMS

Note: Average productivity of producing, domestic firms as a function of τ (collateral constraint parameter) in a model with unconstrained acquirers only ($\hat{A}^{ll^*}$, left panel) and a model with constrained acquirers only ($\hat{A}^{ll}$ right panel). Average productivity is standardized by the average productivity in a model without any acquirers, $\hat{A}^{noacq}$. See text for more details on the calibration.

face liquidity problems. This means that even though the average productivity of firms with liquidity problems, $\hat{A}^{ll}$, rises during liquidity crises, this barely affects the total average productivity because the number of producing firms with liquidity problems is small to begin with.[34] Once again, it should be noted that our earlier result, a *strong* cleansing effect *in* the market for corporate control, is consistent with a *weak* cleansing effect on domestic firms *through* the market for corporate control. A large majority of firms acquired by constrained firms do not face liquidity problems and would have survived on their own. Even though financial crises lead to a strong cleansing effect among these acquired firms, this barely affects the survival rate of domestic firms and therefore does not have a strong cleansing effect on domestic firms.

The figure also illustrates the extent to which acquisitions can substitute for local credit markets. Both the model with foreign (unconstrained) acquirers and domestic (constrained)

[34]Although the quantitative predictions are sensitive to the calibration, the result that the cleansing effect through constrained acquisitions is positive, but very weak is robust to e.g. different ranges of τ and different values for the size difference between acquirers and targets, k.

acquirers feature a higher productivity than the model without acquirers. An economy without any credit markets ($\tau = 0$) sees its productivity increase by 1.8 percent if domestic acquisitions are possible, but by more than 35 percent if it opens up to foreign acquisitions.[35]

2.4 Possible Resale of Acquisitions

The literature on financial crises, especially in emerging markets, has emphasized the resale or "flipping " of crisis time acquisitions as a metric of the long term synergy and viability of such acquisitions (see Acharya et al., 2011; Alquist et al., 2016). The main intuition from that literature is that crisis time foreign acquisitions, if they were mostly driven by valuations based on the target's lack of liquidity, would be sold back after liquidity returned. This mechanism still holds true for foreign acquirers in our model. But we show that a second effect overturns this mechanism for domestic acquirers. During normal times, some domestic acquisitions are flipped over time because the acquirer himself might suddenly need liquidity for its own operations. Domestic firms acquiring targets during financial crises, however, are particularly liquid and are therefore less likely to resell their acquisitions for liquidity purposes. Subsequent flipping rates for domestic acquisitions made during crises are therefore predicted to be relatively low.

To allow for possible resales after acquisitions, we extend the model by an additional period, period 3. The financial crisis occurs at the end of period 1, but is over by the end of period 2, i.e. $\tau_1 = \tau_c$ and $\tau_2 = \tau_n$. Period 3 is a normal period and represents the long run. In period 2, after revenues for that period have been realized, the acquirer receives an all-or-nothing offer V^o for her entire share α of the firm.

We make a number of assumptions to simplify the analysis. The assumptions are that: (i) the new acquirer making the buy-back offer is not liquidity constrained; (ii) the new acquirer

[35] These numbers depend on how pervasive acquisitions are. We assume that *every* firm with liquidity problems is acquired as long as the acquisition is profitable and feasible (there are no search frictions). This clearly overstates the actual number of acquisitions, especially of foreign (unconstrained) acquisitions if search frictions are particularly large for those types of acquisitions. Additionally, the reader should also keep in mind that very large firms ($A > \frac{A^{max}}{k}$) cannot be acquired in the model with constrained acquirers due to our assumption on the size relationship between acquirers and target firms. This automatically reduces the benefits of allowing for constrained acquirers.

has access to the same technology as the original owner of the firm and there are no monitoring costs (i.e. $\phi = 1$ and $c = 0$); (iii) acquirer and seller engage in Nash bargaining over any surplus of an acquisition, with $1 - \psi$ denoting the fraction of the surplus that the acquirer obtains; and (iv) temporary productivities ϵ and ϵ_{acq} follow an AR(1) process with persistence ρ in period 2, but equal their expected values of 1 in period 3 because period 3 represents the long run. This latter assumption simplifies our algebra, but is not crucial to our main result.

We discuss the firms' decision problems in reverse order: First, we show under which conditions acquisitions are resold at the end of the second period. Then, we study the acquisition decision in the first period.

It is optimal for the initial acquirer to resell the firm whenever the outside offer V^o exceeds the value of holding onto the firm. The value of reselling the firm are the expected net profits of production in the third period, $V^{flip} = A(-b + 1)$. The value of holding onto the firm depends on the liquidity position of the post-acquisition entity. If the post-acquisition entity does not face liquidity problems in the second period, it can pay for the upfront costs of production and produces in the third period. Then, the value of holding onto the firm equals the net profits in the third period, $A(-b + \phi) - c$. Alternatively, the firm cannot produce and net profits are 0:

$$V^{keep} = \begin{cases} A(-b+\phi) - c & \text{if} \quad \epsilon_{acq,2} \geq b/\tau_2 \quad \& \quad \epsilon_2 \geq \epsilon_2^l \\ 0 & \text{if} \quad \epsilon_{acq,2} < b/\tau_2 \quad \text{or} \quad \epsilon_2 < \epsilon_2^l, \end{cases}$$

where, as before, ϕ and c denote function values with optimally chosen share α.[36] The outside offer is the sum of the value of holding onto the firm plus a share of the surplus from the transaction. We assume that the initial acquirer and the new acquirer engage in Nash bargaining, so that they share any surplus from the transaction, with share $1 - \psi$ going to the initial acquirer. The surplus from selling is the value if the firm is sold, V^{flip}, minus the value if it is not sold,

[36]The optimal chosen α satisfies $\phi'(\alpha)A\mathbb{E}(\epsilon_2|\epsilon_1) = c'(\alpha)$ in the first period and $\phi'(\alpha)A = c'(\alpha)$ in the second period. In the first part of the paper, we assumed $\mathbb{E}(\epsilon_2|\epsilon_1) = 1$. Allowing for persistence in ϵ does not dramatically change the predictions on the average acquired share in the previous section.

V^{keep}. The outside offer is therefore

$$V^o = V^{keep} + (1 - \psi)\left(V^{flip} - V^{keep}\right)$$

Then, the acquirer sells back the firm if $V^o > V^{keep}$, that is $V^{flip} > V^{keep}$. Here, we distinguish two cases, depending on the post-acquisition entity's liquidity position.

First, consider a post-acquisition entity that has enough liquidity to produce in the third period, i.e. $\epsilon_{acq,2} \geq b/\tau_2$ and $\epsilon_2 \geq \epsilon_2^l$. Then, solving the expression $V^{flip} > V^{keep}$, the acquirer sells back the firm after the second period if $A < \frac{c}{\phi - 1} = A^{tech}$.[37] That is all firms with $A < A^{tech}$ are flipped in the second period. This formalizes the intuition that acquisitions characterized by lower values of A are more likely to be resold. The acquisition is flipped because the target firm no longer requires liquidity.

Second, consider a post-acquisition entity that is liquidity-constrained and does not produce in the third period. Then, it is always profitable to sell back the firm, no matter the value of A. In this case, the target firm is flipped because the acquiring firm no longer has enough liquidity to pay for the upfront production costs. This case is only relevant for constrained acquirers.

Now that we have solved the flipping problem in the second period, we can look at the initial acquisition problem in the first period: A target firm is acquired if an acquisition generates positive surplus, i.e. if the value of a firm being acquired, V_{acq}, exceeds the value of it not being acquired, V_{tar}.

The value of a potential target firm that is not acquired in the first period is

$$V_{tar} = \begin{cases} A\epsilon_1 + 0 + A(-b+1) & \text{if} \quad \epsilon_1 < b/\tau_1 \\ A\epsilon_1 + A\mathbb{E}(\epsilon_2)(-b+1) + A(-b+1) & \text{if} \quad \epsilon_1 \geq b/\tau_1. \end{cases}$$

The value of the firm is the sum of all three periods' profits. First-period (gross) profits are $A\epsilon_1$.

[37] This condition holds if A is small. To see this, note that this inequality can be rewritten as $A > \phi A - c$. The RHS is increasing in A faster than the LHS: $\frac{d\phi A - c}{dA} = \frac{\partial \phi A - c}{\partial A} + \frac{\partial \phi A - c}{\partial \alpha}\frac{\partial \alpha}{\partial A} = \frac{\partial \phi A - c}{\partial A} = \phi > 1$, where the second term drops out because α is chosen optimally.

Expected profits net of fixed costs in the second period are $A\mathbb{E}(\epsilon_2)(-b+1)$ if the firm has paid the upfront costs ($\epsilon_1 \geq b/\tau_1$) and 0 otherwise. The expected value for ϵ_2 is conditional on the realization of ϵ_1 and under the assumption of an AR(1) process equals $\mathbb{E}(\epsilon_2) = 1-(1-\epsilon_1)\rho$. In the second period, the owner of the firm can pay for the fixed cost himself, or, if he does not have enough liquidity, he can sell the firm and the new owner pays for the fixed cost. Either way, the firm produces in the third period generating additional profit $A(-b+1)$.

The value of a firm acquired in the first period is

$$V_{acq} = \begin{cases} A\epsilon_1 + A\mathbb{E}(\epsilon_2)(-b+\phi) - c + A(-b+1) & \text{if} \quad A < A^{tech} \\ A\epsilon_1 + A\mathbb{E}(\epsilon_2)(-b+\phi) - c + p\left(A(-b+\phi)-c\right) + (1-p)\,A(-b+1) & \text{if} \quad A \geq A^{tech}. \end{cases}$$

The first two terms, $A\epsilon_1$ and $A\mathbb{E}(\epsilon_2)(-b+\phi)-c$, are the profit from producing in both the first and second period. In the second period, the acquirer can either resell the firm or hold on to it. If the target firm's long-term productivity level A is low, $A < A^{tech}$, the acquisition gets flipped because the target firm no longer needs liquidity. Then, third-period profits are $A(-b+1)$. If the target firm's long-term productivity level A is high, the acquirer either keeps the acquisition, and profits are $A(-b+\phi)-c$, or he is forced to sell it because he does not have enough liquidity, and profits are $A(-b+1)$. The probability that the post-acquisition entity has enough liquidity, conditional on having had enough liquidity in the first period, is

$$p \equiv \begin{cases} Pr\left(\epsilon_{acq,2} \geq b/\tau_2, \epsilon_2 \geq \epsilon_2^l | \epsilon_{acq,1} \geq b/\tau_1, \epsilon_1 \geq \epsilon_1^l\right) & \text{for constrained acquirers} \\ 1 & \text{for unconstrained acquirers.} \end{cases}$$

Then, after some algebra, the surplus of an acquisition at the end of the first period, $V_{acq} - V_{tar}$, can be written as

$$
S = \begin{cases}
A\mathbb{E}(\epsilon_2)(\phi - b) - c < 0 & \text{if} \quad \epsilon_1 < b/\tau_1 \quad \& \quad A < A^{fire} \\
A\mathbb{E}(\epsilon_2)(\phi - 1) - c < 0 & \text{if} \quad \epsilon_1 \geq b/\tau_1 \quad \& \quad A < A^{tech} \\
A\mathbb{E}(\epsilon_2)(\phi - b) - c \geq 0 & \text{if} \quad \epsilon_1 < b/\tau_1 \quad \& \quad A^{fire} \leq A < A^{tech} \\
A\mathbb{E}(\epsilon_2)(\phi - b) - c + p\left((\phi - 1)A - c\right) > 0 & \text{if} \quad \epsilon_1 < b/\tau_1 \quad \& \quad A \geq A^{tech} \\
\left(\mathbb{E}(\epsilon_2) + p\right)\left(A(\phi - 1) - c\right) \geq 0 & \text{if} \quad \epsilon_1 \geq b/\tau_1 \quad \& \quad A \geq A^{tech}.
\end{cases}
$$

where the inequality signs follow from the restriction on A.

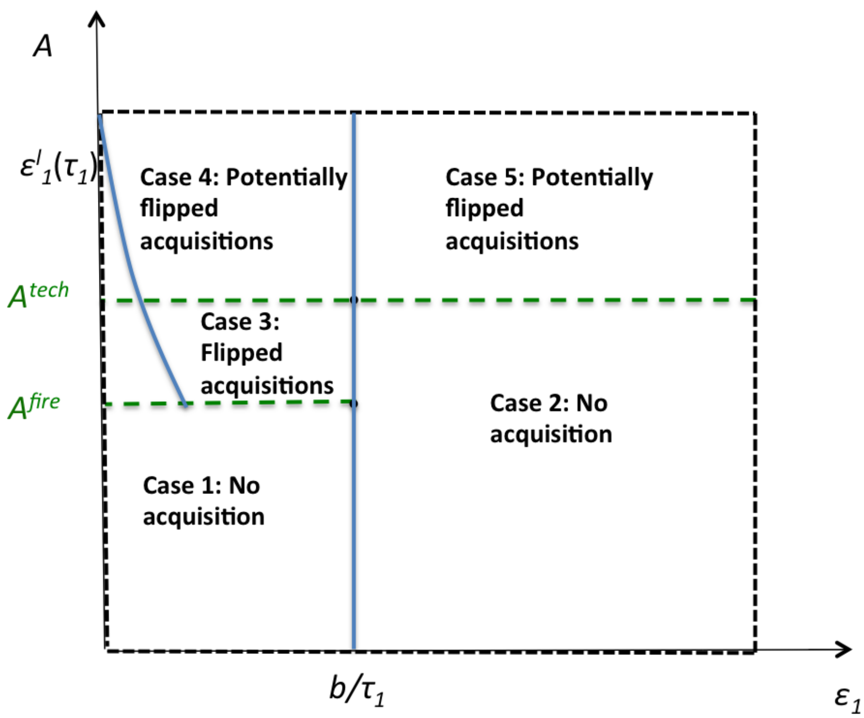


Figure III.8: Resale of Acquired Firms

Note: Figure displays combinations of A and ϵ_1 of a target firm, which can be initially acquired and then resold ('flipping'). The joint borrowing constraint ϵ_1^l is drawn for a constrained acquirer with a given liquidity level $\epsilon_{acq,1}$. For case 3 and 4, only firms with $\epsilon \geq \epsilon^l$ are acquired. See text for further details on the different cases.

Figure III.9 illustrates the resulting five cases: No acquisition takes place in the first two cases because the target firms' productivities are too low. In case 1, exits the market because it lacks liquidity to pay for the upfront cost of production; in case 2, the target firm has enough liquidity to produce. Case 3 gives rise to fire-sale acquisitions that will be flipped at the end of the second period. Finally, cases 4 and 5 above comprise combinations of A and ϵ_1, where initial acquisitions take place, but those technology-driven acquisitions might be flipped at the end of the second period if the acquirer is a constrained firm and realizations of liquidity levels ϵ_2 and $\epsilon_{acq,2}$ are low. Flipping occurs with certainty in case 3 because the target firm no longer needs liquidity; and flipping might occur in cases 4 and 5 if the post-acquisition entity faces liquidity problems. We refer to this last type of flipping as "forced" flipping.

Proposition 5. ***Higher flipping rates for unconstrained acquirers***

Unconstrained acquisitions made during a financial crisis have higher flipping rates, i.e., if $\tau_1 = \tau_c < \tau_1 = \tau_n$ *then* $\frac{n_c^{flip^*}}{n_c} > \frac{n_n^{flip^*}}{n_n}$.

Proof: See Technical Appendix.

Unconstrained acquirers never face liquidity problems and are therefore never 'forced' to flip technology-driven acquisitions (cases 4 and 5). So they only flip fire-sale acquisitions (case 3). That is the proportion of flipped unconstrained acquisitions is simply equal to the share of fire-sale acquisitions in total acquisitions. As shown earlier, this share increases when there is an adverse aggregate financial shock.

For constrained acquirers, the proportion of flipped acquisitions is

$$\frac{n^{flip}}{n} = \frac{n^{fire} + (1-p)n^{tech}}{n^{fire} + n^{tech}}$$

and the derivative is

$$\frac{\partial \frac{n^{flip}}{n}}{\partial \tau_1} = \frac{p\left(\frac{\partial n^{fire}}{\partial \tau_1} n^{tech} - \frac{\partial n^{tech}}{\partial \tau_1} n^{fire}\right)}{n^2} - \frac{\partial p}{\partial \tau_1}\frac{n^{tech}}{n}.$$

This expression suggests that the proportion of flipped acquisitions among constrained acquirers might be lower for crisis-cohort acquisitions for two reasons: The first term refers to changes in the share of fire-sale acquisitions. These fire-sale acquisitions certainly get flipped.

But, as the simulations in the previous section suggest, the share of fire-sale acquisitions does not increase by that much for constrained acquirers during a crisis. This keeps flipping rates low. The second term refers to changes in the number of "forced" resales caused by acquirers running into liquidity problems. These forced flippings will also be low for crisis-cohort acquisitions because crisis-cohort acquirers have more liquidity and are therefore more resilient to forced resales. Only the most liquid firms are able to acquire targets during financial crises. Once the financial crisis is over and borrowing conditions improve, it is unlikely that these high-liquidity firms run into liquidity problems and are forced to resell their acquired firm, assuming some persistence in liquidity, $\rho > 0$. The lower flipping rates observed for crisis-cohort acquisitions are the result of a "selection effect" in the sense that only the most liquid and hence, most resilient firms acquire targets. More formally, $\partial p / \partial \tau_1 < 0$ conditional on τ_2: The probability that the post-acquisition entity has enough liquidity at the end of the second period, p, goes up if the borrowing constraints become tighter in the first period. Importantly, it is the *change* in τ from a low crisis value $\tau_1 = \tau_c$ to a high value $\tau_2 = \tau_n$ that raises the probability p.

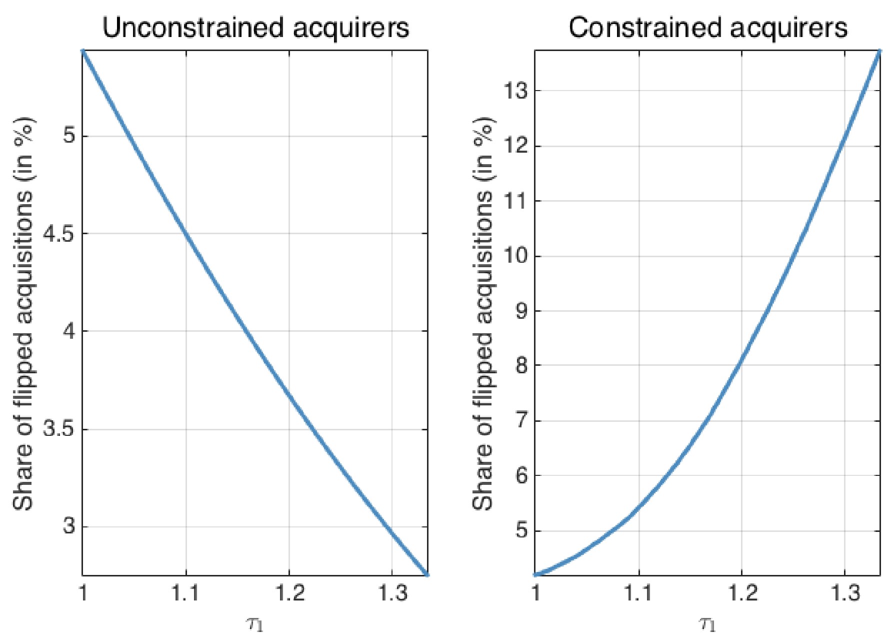


Figure III.9: Share of Flipped Acquisitions

Note: Simulated share of flipped acquisitions as a function of financial constraint in the first period, τ_1, for unconstrained acquirers (left panel) and constrained acquirers (right panel). The collateral constraint during normal times is $\tau_2 = 1.33$. For more details, see notes to Figure III.4.

Figure III.9 shows simulated flipping rates for unconstrained and constrained acquirers as a function of the collateral constraint during the crisis, τ_1. The collateral constraint during normal times is $\tau_2 = 1.33$. An additional parameter of our three-period model is the persistence of the temporary productivity, ρ. There is little guidance in the literature on this parameter, but it is probably little controversial to assume some persistence. We set $\rho = 0.9$, but our results remain robust even for very low values of ρ.[38] For the chosen parameters, flipping rates increase for unconstrained acquirers from 2.8 to 5.5 percent, but decrease for constrained acquirers from more than 13 to 4 percent for domestic acquirers. We later take this hypothesis to the data, that flipping rates for domestic (constrained) acquirers decrease and converge to flipping rates observed for unconstrained acquirers.

3 Testing the Implications of the Model

The theory gives us two sets of testable implications regarding the size and flipping rates of domestic and foreign acquisitions in times of financial distress, in comparison to normal times. To test these, we need transaction level data for mergers and acquisitions. Our source for this is the Thompson-Reuters Securities Data Company Platinum database, which contains information on the universe of such deals in a large set of EMEs.[39] For each transaction, we mainly utilize a few key variables – the share of a firm acquired, the names of the firms involved, their primary SIC industry classifications, the country of origin of the acquirer, and the date on which the transaction was completed – for sixteen of the largest markets for corporate control in EMEs between 1990 and 2007.[40]

Due to the structure of the hypotheses, which are essentially comparisons of two kinds of

[38]If there were no persistence, the share of flipped acquisitions for domestic acquirers would be higher for the crisis cohort than for the non-crisis cohort. But even a persistence parameter as low as $\rho = 0.05$ is sufficient to reverse this prediction.

[39]See Alquist et al. (2016) for a detailed description of the SDC data.

[40]The countries are Argentina, Brazil, Chile, China, India, Indonesia, Malaysia, Mexico, Peru, Philippines, Singapore, South Africa, South Korea, Taiwan, Thailand, and Vietnam. Our data contains both private and publicly listed firms.

acquisitions (relatively financially constrained and unconstrained acquisitions, proxied by those made by domestic and foreign acquiring firms, respectively), across two macroeconomic regimes (normal and adverse financial shock), we employ a difference-in-difference approach. To test whether there is convergence in the size of acquisitions between foreign and domestic acquisitions during an adverse financial shock, we estimate the following linear model:

$$fracacq_{kjct} = \beta_{jc}\boldsymbol{\delta}_{jc} + \beta_C D_C^{ct} + \beta_F D_F^{kjct} + \beta_{C,F} D_{C,F}^{kjct} + \boldsymbol{controls}_{c,t-4}^{'}\beta_{mc} + \epsilon_{kjct}. \qquad \text{(III.8)}$$

Here k, j, c, and t stand for transaction, single-digit SIC industry of the target firm, country, and time, respectively. The dependent variable is the fraction of the target firm acquired in transaction k. The two main independent variables are D_{ct}^C, that indicates whether an acquisition took place during a period when there was an aggregate adverse financial shock, and D_F^{kjct}, which indicates whether the acquirer involved in a particular transaction is a foreign firm. We also include a vector of fixed effects $\boldsymbol{\delta}_{jc}$ and a set of lagged country-level macroeconomic controls $\boldsymbol{controls}_{c,t-4}$. The standard errors are clustered two-way along the cross-sectional (country×target-industry) and time (month) dimensions.[41] Since $fracacq_{kjct} \in [0, 1]$, a linear model might potentially lead to predicted values outside this range. Hence we also estimate β_C , β_F and $\beta_{C,F}$ in a Generalized Linear Model (GLM) framework using maximum likelihood. This takes into account the bounded nature of our dependent variable (see Papke and Wooldridge, 1996). D_{ct}^C, which serves as our proxy for an aggregate adverse financial shock, is defined using the (annual) systemic banking crises dates from Laeven and Valencia (2010).[42] $D_F^{kjct} = 1$ when the acquirer is from a developed market, which is in the spirit of our theoretical model. The results are insensitive to defining foreign firms simply as those not from the target's country because the vast majority of our foreign acquirers are from developed markets. Following Brown

[41] This procedure adjusts for the possible correlation of the error terms within the same country×target-industry, as well as among firms within the same month. Petersen (2009) shows that failing to cluster along multiple dimensions can lead to deflated standard errors in firm level studies and provides code to implement inference in Stata.

[42] See Alquist et al. (2016) for a detailed discussion on the arguments in favor of using the banking crisis dates as a proxy for financial shocks, as opposed to currency or twin crises.

and Dinc (2011), lagged macroeconomic variables are used to control for the business cycle determinants of M&A activity.[43] Alquist et al. (2016) find regional differences (especially, between Asia and Latin America) in their empirical analysis of acquisitions in emerging economies. Hence, we report results for our full sample, for Asia, and for all other countries.

As noted before, we identify the effects predicted by the models empirically using the assumption that domestic acquirers are constrained, while foreign acquirers are not, and that the banking crisis dates proxy an adverse financial shock for all firms in a country. Based on the theory, we frame two key empirical hypotheses regarding the coefficients β_C and $\beta_{C,F}$ in Regression III.8.[44] Note below that we do not frame hypotheses involving β_F, which measures the difference in acquired shares during normal times between foreign and domestic acquisitions. We want to focus on the comparative static results of a financial shock rather than the initial or final level differences in acquired shares, which could be due to differences in technology between constrained (domestic) and unconstrained (foreign) firms that are not part of the model. Accordingly, we remain agnostic about the sign of β_F and interpret its estimates in the context of the literature.

(i) β_C: Domestic acquisitions involve larger stakes during a banking crisis, i.e., $\beta_C > 0$.

(ii) $\beta_C + \beta_{C,F}$: We expect crisis-time foreign acquisitions to involve smaller stakes, i.e., $\beta_C + \beta_{C,F} < 0$.

The results are shown in Tables III.2 and III.3 for the OLS and GLM estimations, respectively. We find strong empirical support for our two key hypotheses in the full sample of acquisitions, with some regional differences that are discussed below. First, domestic acquisitions involve significantly higher stakes during crises. The point estimate for the full sample and the unconditional mean fraction acquired in the sample (about 63%) for domestic acquisitions indicates a 6.3% increase in the size of domestic acquisitions during crises. The model also does well on the

[43]Specifically, they are the change in the nominal exchange rate (quarterly), the use of IMF credit and loans as a percentage of a country's quota (quarterly), real GDP per capita (annual), and real GDP growth (annual). The data sources are the Penn World Tables, the IMF's *International Financial Statistics*, Taiwan's National Statistical Office, and the Central Bank of the Republic of China. More details and descriptions of the macroeconomic controls are provided in Alquist et al. (2016).

[44]The baseline group in the regression is $(\beta_C = 0, \beta_F = 0)$, i.e., domestic acquisitions during normal times.

second prediction. By the OLS estimates, crisis-time foreign acquisitions are found to be smaller, though not significantly so, in the full and non-Asian sample, while they are significantly smaller in the Asian samples. The GLM estimates suggest that they are significantly smaller in the full sample as well.

The sign and significance of β_F and $\beta_F + \beta_{C,F}$ can be interpreted using the model. The estimates of β_F suggest that foreign and domestic acquisitions do not differ significantly during normal times in the full sample, but this result masks large regional differences. In particular, the GLM results show that foreign stakes are significantly larger than domestic ones during normal times in the Asian samples, while the opposite is true for the non-Asian sample (mostly Latin America). These two cancel out in the full sample to yield an insignificant coefficient on the foreign acquisition dummy. Through the lens of our model, this finding is consistent with foreign-owned firms being engaged in acquisitions that lead to long-term synergies in Asia, and being more productive than domestic firms. There is ample evidence in the literature in favor of the latter point (see Yasar and Morrison Paul, 2007; Blalock and Gertler, 2008; Arnold and Javorcik, 2009). Next, note that $\beta_F + \beta_{C,F} < 0$, i.e., foreign stakes acquired during crises are significantly smaller than domestic stakes acquired during crises, in all the samples using both OLS and GLM estimates. These two results together point to a "convergence" in the size of stakes acquired in foreign and domestic acquisitions during financial crisis episodes. Recall that this convergence is one observable implication of the change in the relative average productivity of constrained and unconstrained acquisitions in a crisis. It is a distinctive prediction of our model and suggests the existence of "cleansing effect", whereby only the most productive domestic acquiring firms in a country hit by a negative financial shock are able to compete in the market for corporate control.

To test whether there is convergence in the flipping rate of acquisitions between foreign and domestic acquisitions during crisis times, we estimate a Cox proportional hazards model of the

Table III.2: Average Size of Ownership Stakes: OLS

	Full	Asia	Post-1997 Asia	Non-Asia
$\hat{\beta}_C$	0.04^a	0.04^a	0.03^b	0.02
	(0.01)	(0.01)	(0.01)	(0.03)
$\hat{\beta}_F$	0.00	0.02	0.03	-0.04^a
	(0.01)	(0.02)	(0.02)	(0.01)
$\hat{\beta}_{C,F}$	-0.07^a	-0.09^a	-0.09^a	-0.03
	(0.02)	(0.02)	(0.03)	(0.04)
No. obs.	29,728	20,410	17,524	9,318
R^2	0.091	0.078	0.086	0.054
Macroeconomic Controls	Yes	Yes	Yes	Yes
Country×Target-Industry Fixed Effects	Yes	Yes	Yes	Yes
	Linear Combination Tests			
	Foreign Crisis Versus Foreign Non-Crisis			
$H_0 : \beta_C + \beta_{C,F} = 0$	-0.03	-0.05^b	-0.06^b	-0.01
	(0.02)	(0.02)	(0.02)	(0.02)
	Foreign Crisis Versus Domestic Crisis			
$H_0 : \beta_F + \beta_{C,F} = 0$	-0.07^a	-0.07^a	-0.06^a	-0.07^c
	(0.02)	(0.02)	(0.02)	(0.04)

Notes: The table reports the point estimate of the coefficient associated with the banking crisis dummy β_C, foreign acquisition dummy β_F and their interaction term $\beta_{C,F}$ obtained from a linear model. The regression is Equation III.8 in the text. The dependent variable is the fraction of a firm acquired. It is based on the full sample of acquisitions by domestic and foreign acquirers. The dates for the domestic banking crises are from Laeven and Valencia (2010). a, b and c indicate statistical significance at the 1%, 5% and 10% levels, respectively. Standard errors, clustered two-way at the level of country×target-industry and month, are reported in parentheses. The coefficient estimates for the country×target-industry fixed effects and the macroeconomic controls lagged four quarters are omitted from the table to conserve space.

Table III.3: Average Size of Ownership Stakes: GLM

	Full	Asia	Post-1997 Asia	Non-Asia
$\hat{\beta}_C$	0.21^a	0.20^a	0.16^a	0.08
	(0.04)	(0.05)	(0.05)	(0.08)
$\hat{\beta}_F$	-0.00	0.08^a	0.13^a	-0.21^a
	(0.02)	(0.03)	(0.03)	(0.04)
$\hat{\beta}_{C,F}$	-0.33^a	-0.40^a	-0.39^a	-0.13
	(0.06)	(0.07)	(0.08)	(0.10)
No. obs.	29,728	20,410	17,524	9,318
Log L	-15,905	-11,233	-9,591	-4,655
Macroeconomic Controls	Yes	Yes	Yes	Yes
Country×Target-Industry Fixed Effects	Yes	Yes	Yes	Yes
	Linear Combination Tests			
	Foreign Crisis Versus Foreign Non-Crisis			
$H_0 : \beta_C + \beta_{C,F} = 0$	-0.12^b	-0.20^a	-0.24^a	-0.05
	(0.05)	(0.06)	(0.07)	(0.07)
	Foreign Crisis Versus Domestic Crisis			
$H_0 : \beta_F + \beta_{C,F} = 0$	-0.33^a	-0.32^a	-0.26^a	-0.34^a
	(0.05)	(0.07)	(0.07)	(0.09)

Notes: The table reports the point estimate of the coefficient associated with the banking crisis dummy β_C, foreign acquisition dummy β_F and their interaction term $\beta_{C,F}$ obtained from the Generalized Linear Model. The dependent variable is the fraction of a firm acquired. It is based on the full sample of acquisitions by domestic and foreign acquirers. The dates for the domestic banking crises are from Laeven and Valencia (2010). a, b and c indicate statistical significance at the 1%, 5% and 10% levels, respectively. Robust standard errors are reported in parentheses. The coefficient estimates for the country×target-industry fixed effects and the macroeconomic controls lagged four quarters are omitted from the table to conserve space.

following form:

$$\ln[h_{jc}(\tau|\mathbf{X})] = \ln[h_{jc}(\tau)] + \beta_C D_C^{ct} + \beta_F D_F^{kjct} + \beta_{C,F} D_{C,F}^{kjct} + \boldsymbol{controls}_{c,t-4}^{'}\beta_{mc} + \epsilon_{kjct} \quad \text{(III.9)}$$

where **X** is a vector of independent variables as defined before. The only new object is the estimated hazard function $h_{jc}(\tau)$, which is the probability density that an average firm experiences an acquisition event in a small interval of time $\Delta\tau$, conditional on it not having been the target of an acquisition for τ units of time since the last acquisition event.[45]

We frame two empirical hypotheses regarding the coefficients β_C and $\beta_{C,F}$ in Regression (III.9). For the reasons outlined before we do not frame hypotheses involving β_F and instead interpret the estimates through the lens of the model. Note that a positive coefficient in the Cox model indicates a higher hazard, i.e., a higher risk of flipping.

(i) β_C: Domestic acquisitions undertaken during a banking crisis (compared to domestic acquisitions during normal times) have lower subsequent hazard rates, i.e., $\beta_C < 0$.

(ii) $\beta_C + \beta_{C,F}$: Foreign acquisitions undertaken during a banking crisis (compared to foreign acquisitions during normal times) have higher subsequent hazard rates, $\beta_C + \beta_{C,F} > 0$.

The results of the Cox regression estimation are shown in Table III.4. Our first prediction cannot be rejected. The coefficient β_C is negative and statistically significant in all the samples. The second prediction is weakly rejected by the data. The point estimates in all the samples are negative, though they are insignificant in three out of the four samples (it is significant at 5% in the post-1997 Asia sample).

In addition, the model offers economic interpretations of the two other empirical results.

[45]The duration τ of an acquisition is measured as follows. We first identify firms that appear at least twice in our data as a target firm, which implies: (a) either that the first acquirer sold off her stake in the second acquisition if the initial acquisition involved 100% of the firm; (b) a different prior owner sold a stake in the firm. Since we are interested only in resales by acquirers, we limit ourselves to 50% or 100% acquisitions (we report results for the former) because we are more confident in those cases that the initial buyer was flipping her acquisition. Under this assumption, the initial transaction identifies the beginning of the relationship. The second sale is thus assumed to mark the end of the immediately preceding ownership relationship, and so on for subsequent appearances by the same target in the dataset. The duration of an acquisition is thus the distance in time between each transaction involving the same target. A detailed discussion about the merits and drawbacks of this method can be found in Alquist et al. (2016).

TABLE III.4: DIVESTITURE RATES

	Only Majority Acquisitions			
	Full	Asia	Post-1997 Asia	Non-Asia
$\hat{\beta}_C$	-0.27^b	-0.46^a	-0.68^a	0.31^c
	(0.13)	(0.15)	(0.15)	(0.17)
$\hat{\beta}_F$	-0.18^b	-0.35^a	-0.29^b	0.10
	(0.08)	(0.11)	(0.13)	(0.09)
$\hat{\beta}_{C,F}$	0.12	0.35^b	0.27	-0.43^c
	(0.16)	(0.17)	(0.19)	(0.26)
No. Obs.	21,216	13,830	12,085	7,386
Log L	-8,685	-5,932	-4,641	-2,735
Macroeconomic Controls	Yes	Yes	Yes	Yes
Country×Target-Industry Stratification	Yes	Yes	Yes	Yes
	Linear Combination Tests			
	Foreign Crisis Versus Foreign Non-Crisis			
$H_0 : \beta_C + \beta_{C,F} = 0$	-0.15	-0.10	-0.41^b	-0.12
	(0.13)	(0.18)	(0.19)	(0.17)
	Foreign Crisis Versus Domestic Crisis			
$H_0 : \beta_F + \beta_{C,F} = 0$	-0.07	0.01	-0.01	-0.33
	(0.15)	(0.15)	(0.16)	(0.25)

Notes: The table reports the point estimates of the coefficients associated with the banking crisis dummy β_C, foreign acquisition dummy β_F, their interaction term $\beta_{C,F}$ and the fraction owned after the acquisition $\beta_{fracownaft}$ obtained from the Cox regression model. The regression is Equation III.9 in the text. The dependent variable is the hazard rate of an acquisition. It is based on the full sample of acquisitions by domestic and foreign acquirers in which post-acquisition stake is at least 50%. The dates for the domestic banking crises are from Laeven and Valencia (2010). Standard errors are reported in parentheses. a, b and c indicate statistical significance at the 1%, 5% and 10% levels, respectively. The coefficient estimates for the macroeconomic controls lagged four quarters are omitted from the table to conserve space.

From the second row of coefficients in Table III.4, $\beta_F < 0$ and significantly so in three out of the four samples. This indicates that foreign acquisitions in normal times have lower divestiture rates than domestic ones. Through the lens of our model, this suggests that foreign acquirers in Asia, on average, completed acquisitions that had higher technological synergies than domestic acquirers, a finding that is consistent with our earlier result that foreign acquisitions in Asia also resulted in larger stakes. Next, we find that $\beta_F + \beta_{C,F}$ is not significantly different from zero, which says that foreign and domestic acquisitions of the crisis cohort do not have different divestiture rates. These two findings together point to a convergence in divestiture rates between foreign and domestic acquisitions after an adverse financial shock: While the divestiture rates of foreign acquisition are significantly lower than domestic ones for the normal-time cohort, the two are statistically indistinguishable for the crisis cohort.[46]

We perform a few checks to assess the sensitivity of our baseline results to alternative empirical specifications. First, we use an alternative proxy for an aggregate financial shock, making use of the annual banking crisis dates from Reinhart and Rogoff (2009) instead of our baseline dating scheme from Laeven and Valencia (2010). Our results are insensitive to this alternative. The reader might also wonder if our macroeconomic control variables (change in the nominal exchange rate, the use of IMF credit and loans as a percentage of a country's quota, real GDP per capita, real GDP growth), that are meant to control for normal business cycle fluctuations in our dependent variables, may be influencing the estimated effect of the financial crisis indicators. To check this, we estimate all the reported regressions without including macroeconomic controls. The results (not reported) show that all our conclusions remain unchanged. In fact, quite intuitively, the point estimates of the crisis effects increase marginally in magnitude when the macroeconomic controls are excluded from the regression. Third, we perform all our estimations excluding financial sector acquiring firms from the sample, as these acquisitions might be driven

[46] A specification that controls for the fraction of the firm that is acquired or the fraction that is owned after a transaction yields very similar results. We prefer not to control for the fraction acquired in our baseline specification because our theory suggests that the size, like the duration, is a reflection of the underlying quality of the match between the acquiring and target firms. Thus using it as a control would introduce endogeneity. The estimate of the coefficient on the fraction acquired is negative and significant (i.e., larger stakes reduce the hazard of a divestiture), which is in line with the theory.

by quite different considerations. For example, investment banks or private equity investors might intrinsically buy smaller stakes and flip their acquisitions faster than, say, acquiring firms that are in the manufacturing sector. Then, some of the patterns we find might simply be driven by proportionately larger increases and declines in foreign financial and domestic financial acquisitions during a financial crisis, respectively. All our results turn out to be robust to excluding financial acquiring firms from the estimation sample. The results of the above robustness checks are excluded from the paper for conciseness but are available upon request from the authors.

To summarize our empirical results, we find strong empirical support for all our predictions regarding the fraction of a firm acquired. Our evidence on divestiture rates generally favors the mechanism highlighted by the model. In particular, we find evidence for convergence during financial crises of both the fraction acquired and divestiture rates between domestic and foreign acquisitions.

4 Conclusion

This paper provides a simple analytical framework for assessing the effects of adverse aggregate financial shocks on the market for corporate control. We model two kinds of acquiring firms: Those operating under financial constraints similar to target firms, and those that are financially unconstrained. Using the model, we first show that adverse financial shocks lead to only the most productive domestic firms, which are themselves financially constrained, performing acquisitions. This is contrast to foreign acquisitions, who perform more fire-sale acquisitions that may have lower productivity. Intuitively, larger and more productive domestic firms are less subject to credit constraints and find it easier to raise financial resources to complete acquisitions. Interpreting constrained and unconstrained acquiring firms as domestic and foreign acquirers in a large dataset of emerging market acquisitions spanning the years 1990-2007, we provide evidence of an increase in the stakes acquired in domestic acquisitions, as well as a novel "convergence" in divestiture rates of foreign and domestic acquisitions in the crisis cohort, as predicted by the model.

We also provide theoretical insight into the cleansing effect of financial crises on the aggregate economy. In this respect, we show that the presence of a market for corporate control has important implications for the traditional cleansing effect. In particular we show, using simulations, that the presence of foreign acquiring firms leads to much larger positive cleansing effects of financial shocks than having only domestic acquirers. Our theoretical results clearly show that allowing, or even facilitating, foreign acquisitions during periods of aggregate financial stress not only has the function of liquidity provision (which has been stressed in the literature so far), it also has a positive cleansing effect on aggregate productivity. While the number of foreign acquisitions is often small compared to the total number of firms in the economy, these often involve medium or large sized firms that are of great importance in terms of market value and employment. A cleansing effect within that group of firms is thus likely to have large aggregate consequences.

It is worth stressing that our contrasting results for unconstrained (foreign) and constrained (domestic) acquisitions highlight the role of firm level borrowing constraints, which in our model comprise the *only* difference between firms, in determining which financially constrained firms remain active in the market for corporate control. It should be noted that this is a deliberate modelling choice, and done to demonstrate the effect we are after—the difference in the behavior of foreign and domestic firms when the latter are faced by financial shocks—most cleanly. Thus our results have mostly focussed on the comparative statics of a financial shock rather than the initial level differences in the variables of interest (such as shares acquired and divestiture rates), which could be due to differences in technology between foreign and domestic firms that are explicitly excluded in the model.

The paper has a rich set of firm level predictions regarding the joint distribution of productivity and financial liquidity for acquirers and targets, as well as the aggregate cleansing effect, that we do not test. Using firm level balance-sheet data from select EMEs to explore these predictions is a fruitful direction for future work. Also, while applied to the data in the context of

EMEs, the model in this paper is equally applicable to acquisitions in developed markets, for which better quality and more extensive firm-level data exist, and where financial liquidity has also been shown to be important for the M&A process (see Almeida et al., 2011; Erel et al., 2015). The model can thus help guide future empirical work on the role of productivity and financial constraints in the market for corporate control in these countries. These and other investigations are left for future work.

Conclusion

This dissertation has analyzed how a country's trade openness affects its set of policy options in the face of economic crises. The first chapter has provided empirical evidence that exporting and importing firms react to exchange rate movements. Exchange rates are therefore an important channel of monetary policy in open economies. Whether monetary policy becomes more or less effective as an economy opens up to trade depends on the trade elasticity to price changes. In the particular case of the elasticity estimate presented in the first chapter, a country's openness barely affects the effectiveness of monetary policy. This result has important implications for monetary policy in a currency union. The Euro area, for instance, is composed of a few large and relatively closed countries like France, Italy and Germany, but also many smaller and open countries like Belgium and the Baltic countries. Countries also differ in their exposure to non-euro-area trade. This heterogeneity, combined with imperfect movements of production factors, can potentially pose a challenge to monetary policy (in addition to the challenge of potentially asymmetric shocks across countries). But the results presented in the first chapter suggest that, despite this heterogeneity, a common monetary policy is likely to have symmetric effects across all member countries.

The second chapter contributes to the debate on austerity policies in Europe. It provides empirical evidence that shortfalls in government purchases are associated with lower-than-predicted GDP and inflation, but such a relationship cannot be established for government revenue. The implied multiplier on government purchases of 1.3 is relatively large and shows that fiscal policy is still quite effective in open economies, at least in the data. The multi-country DSGE model qualitatively replicates the effects of government purchases shortfalls on macroeconomic aggregates observed in the data. A challenge for the model is to replicate the large multiplier observed in the data. In future work, it will be used to analyze the role of exchange rate policies, trade openness and fiscal spillover effects in shaping the economies' response to austerity policies.

The last chapter analyzes a third set of macroeconomic policies that promote (cross-border) M&As. The chapter shows that M&As can substitute for bank lending to allocate resources towards more productive firms. Promoting M&As can therefore be an important tool in times of financial crises and tight bank lending. The presented quantitative model suggests that M&As can be particularly helpful if the acquiring firm is foreign and not subject to tighter financial constraints. Just promoting domestic M&As is not sufficient because domestic acquirers themselves have little access to capital during financial crises. These results are informative of the current economic situation in Europe. The global market for corporate control experienced a large drawback during the Great Recession and has not fully recovered since then. At the same time, the recovery across European economies has been very unequal, and whereas credit spreads have increased in periphery countries, financial capital is abundant in core countries like Germany and Switzerland. The low take-off in cross-border M&A rates is therefore surprising and indicates potentially large benefits of policies promoting those cross-border M&As.

Appendices

Appendix A Empirical Part

Derivation of changes in firm performance measures

In this section, I derive expressions for changes in the nominal output, labor, nominal intermediate consumption and nominal value added. In the derivation, I make use of the following two equations describing changes in the output price and changes in marginal costs:

$$
\begin{aligned}
\mathbb{E}\left(d\log p^i\right) &= -d\log E_X^i + (1-\theta) d\log MC^i \\
d\log MC^i &= \gamma^i d\log W + (1-\gamma^i)\left(d\log E_M^i + d\log v_z^i\right).
\end{aligned}
$$

Equations (I.2) shows the change in real output. The change in nominal output is the change in real output plus the change in the export price index quoted in Estonian kroons:

$$
\mathbb{E}\left(d\log(p_k^i y^i)\right) = \mathbb{E}\left(d\log p_k^i - \psi d\log p^i\right) + d\log D^i.
$$

For sticky-price firms, the change in the export price index in kroons equals the effective exchange rate of the invoicing currency. For flexible price firms, the change in the export price index is the change in marginal costs. Then, defining $d\log E_\$^i = \sum_{n\in\mathbb{X}_\$^i} \frac{y_\$^i}{y^i} d\log E_\$$, the change in nominal output is

$$
\begin{aligned}
\mathbb{E}\left(d\log(p_k^i y^i)\right) &= \theta d\log E_\$^i + (1-\theta) d\log MC_k^i - \psi\mathbb{E}\left(d\log p^i\right) + d\log D^i \\
&= \psi d\log E_X^i + \theta d\log E_\$^i + (1-\psi)(1-\theta) d\log MC^i + d\log D^i
\end{aligned}
$$

And inserting the expression for $d\log MC^i$ gives

$$
\begin{aligned}
\mathbb{E}\left(d\log(p_k^i y^i)\right) = {} & \psi d\log E_X^i + \theta d\log E_\$^i + d\log D^i \\
& + (1-\psi)(1-\theta)\left[(1-\gamma^i) d\log E_M^i + \gamma^i d\log W + (1-\gamma^i) d\log v_z^i\right].
\end{aligned}
\tag{III.10}
$$

Using nominal output instead of real output does not change the coefficient on $d\log E_X^i$, ψ. To gain intuition for this result, consider an Estonian firm that exports in Estonian kroons to

Russia. If the Russian ruble appreciates, the Estonian firm will increase its exports because its export price in rubles has gone down. However, its export price in kroons is unaffected. Since the export price in kroons is unaffected, real and nominal exports are the same. This is no longer true if the Estonian firm invoices in a different currency. I therefore add $\theta d \log E^i_\$$ as an additional covariate that controls for changes in the invoicing currency exchange rate.

To derive the change in labor and the value of intermediate consumption, I have to make assumptions on the production function. I assume a CES production function in labor and intermediate consumption with an elasticity of substitution ϵ. Its log-linearized form is

$$\mathbb{E}\left(d\log y^i\right) = \gamma^i d\mathbb{E}\left(\log l^i\right) + (1-\gamma^i)\mathbb{E}\left(d\log q^i\right).$$

Inserting the optimal factor employment condition

$$\mathbb{E}\left(d\log q^i\right) = \mathbb{E}\left[d\log l^i\right) - \epsilon\left(d\log v^i - d\log W\right)$$

gives

$$\mathbb{E}\left(d\log y^i\right) = \mathbb{E}\left(d\log l^i\right) - (1-\gamma^i)\epsilon\left(d\log v^i - d\log W\right).$$

Using $\mathbb{E}\left(d\log y^i\right) = -\psi d\log p^i + d\log D^i$, gives an equation for $\mathbb{E}\left(d\log l^i\right)$

$$\begin{aligned}\mathbb{E}\left(d\log l^i\right) &= -\psi\mathbb{E}\left(d\log p^i\right) + d\log D^i + (1-\gamma^i)\epsilon\left(d\log v^i - d\log W\right)\\ &= \psi d\log E^i_X - \psi(1-\theta)(1-\gamma^i)d\log E^i_M - \psi(1-\theta)\left(\gamma^i d\log W + (1-\gamma^i)d\log v^i_z\right)\\ &+ d\log D^i + (1-\gamma^i)\epsilon\left(d\log v^i - d\log W\right),\end{aligned}$$

which can be simplified to (using $d\log v^i = d\log E^i_M + d\log v^i_z$)

$$\begin{aligned}\mathbb{E}\left(d\log l^i\right) = \psi d\log E^i_X - (1-\gamma^i)\left[\psi(1-\theta) - \epsilon\right]\left(d\log E^i_M + d\log v^i_z\right)\\ - \left[\epsilon - \gamma^i\left(\epsilon - \psi + \theta\psi\right)\right]d\log W + d\log D^i\end{aligned} \tag{III.11}$$

Similarly, the value of intermediate consumption is

$$\mathbb{E}\left(d\log(v^iq^i)\right) = \mathbb{E}\left(d\log l^i\right) + \epsilon d\log W + (1-\epsilon)d\log v^i$$

or:

$$\begin{aligned}\mathbb{E}\left(d\log(v^iq^i)\right) = \psi d\log E_X^i - &\left[(1-\gamma^i)\psi(1-\theta) - 1 + \epsilon\gamma^i\right]\left(d\log E_M^i + d\log v_z^i\right) \\ &+ \gamma^i\left(1-\psi+\theta\psi\right)d\log W + d\log D^i\end{aligned} \tag{III.12}$$

The effect of changes in the export exchange rate on both labor and the value of intermediate consumption is the same and given by ψ. Intuitively, a depreciation of the export exchange rate raises demand for a firm's output and hence, it will demand more inputs one-for-one with the output change. The effect of a change in the import exchange rate is ambiguous. Generally, one can distinguish two effects of a depreciation of the import exchange rate, which raises the price of imports:

1. Marginal costs increases and to the extent that the firm can adjust its output price, demand will go down and the firm will demand fewer inputs. The magnitude of this effect depends on the demand elasticity ψ and the share of firms with flexible prices, $(1-\theta)$.

2. Labor becomes more attractive, especially if the elasticity of substitution between intermediates and labor is high, i.e. ϵ is large.

For labor the coefficient on the import exchange rate is negative if ϵ is low, ψ is high and θ is low. For intermediate consumption, the coefficient is negative if ϵ is high, ψ is high and θ is low. Note that the coefficient is not proportional to $(1-\gamma^i)$ if $\epsilon \neq 1$.

Equations (III.10) to (III.12) are the equations describing changes in nominal gross output, labor and nominal intermediate consumption that I estimate in the empirical section.

Construction of variables for empirical analysis

The following equations show the construction of my independent variables:

$$\Delta \log E^i_{X,t} = s^i_{X,t} \sum_{n \in \mathbb{X}^i} \left(s^i_{X,n,t} \Delta \log E_{n,k,t} - \theta \sum_{\$} \left(s^i_{X,n,\$,t} \Delta \log E_{n,\$,t} \right) \right)$$

$$\Delta \log E^i_{M,t} = \Delta s^i_{M,t} \sum_{n \in \mathbb{M}^i} \left((1-\theta) s^i_{M,n,t} \Delta \log E_{n,k,t} + \theta \sum_{\$} \left(s^i_{M,n,\$,t} \Delta \log E_{n,\$,t} \right) \right)$$

$$\Delta \log v^i_{z,t} = s^i_{M,t} \sum_{n \in \mathbb{M}^i} \left(s^i_{M,n,t} \Delta \log v_{z,n,t} \right) + \left(1 - s^i_{M,t}\right) \Delta \log v_{EE,,t}$$

$$\Delta D^i_{y,t} = \left(1 - s^i_{X,t}\right) \Delta \log Y_{EE,t} + s^i_{X,t} \sum_{n \in \mathbb{X}^i} \left(s^i_{X,n,t} \Delta \log Y_{n,t} \right)$$

$$\Delta D^i_{p,t} = \left(1 - s^i_{X,t}\right) \Delta \log P_{EE,t} + s^i_{X,t} \sum_{n \in \mathbb{X}^i} \left(s^i_{X,n,t} \Delta \log P_{n,t} \right).$$

The first two indices are the effective export and import exchange rate as defined in (I.9) and (I.10). Trade shares are given by s, with the X subscript denoting exports and the M subscript denoting imports. For instance, the shares $s^i_{X,t}$ are averages of period $t-1$ and t shares of a firm's export value in total output, and the shares $s^i_{M,t}$ are shares of a firm's import value in total material costs. The shares $s^i_{X,n,\$,t}$ are average shares of export values to country n in currency $\$$ in the firm's total exports. Taking the average across $t-1$ and t takes into account that firms substitute across source countries when facing relative price changes.[47] For the exchange rates $E_{n,\$,t}$, the first subscript n indicates the country and the second subscript indicates the invoicing currency $\$$. I allow for firms exporting to the same country n in different currencies $\$$. I therefore sum over all invoicing currencies $\$$ and weight them by their respective shares $s^i_{X,n,\$,t}$ in total exports. The exchange rate of the invoicing currency is provided by Statistics Estonia and measured as the average exchange rate of the month that the transaction took place. I calculate the exchange rate of the destination currency myself, using the annual average rate as it is listed in the UN national accounts database.[48]

[47] The resulting price index is very similar to Fisher's ideal price index.

[48] See http://unstats.un.org/unsd/snaama/dnlList.asp. I only have access to trade data aggregated at the annual level.

The third index $\Delta \log v_{z,t}^i$ reflects changes in producer prices both abroad and in Estonia. The terms $v_{z,n,t}$ are measured as the producer price index of manufactured goods in country n or the GDP deflator, depending on data availability.[49]

For the indices for absorption and the price level in the destination markets, $\Delta D_{y,t}^i$ and $\Delta D_{p,t}^i$, I use the GDP deflator in country n for $P_{n,t}$ and real GDP for $Y_{n,t}$, taken from the UN national accounts database.

Changes in wages, $\Delta \log W_t$, are measured by sector-specific labor cost indices provided by Statistics Estonia.[50]

I calculate γ^i as the average share of labor costs in total costs (= a firm's wage bill plus total material costs) for each firm, averaging over all available years that the firm is in my dataset.

Consistency of estimator

In my empirical analysis, I estimate a regression of the form[51]

$$d \log y_t^i = \psi d \log E_{X,t}^i + \varepsilon_t^i. \tag{III.13}$$

[49]Several sources are used for the producer price index. For most European countries, Eurostat data on non-domestic PPI is used ('sts_inppnd_a'). If available, the non-domestic industry sector output price index for the euro area is used; if not, the general non-domestic industry sector output price index is used. Estonia's producer price index is $v_{EE,t}$. All producer price indices and GDP deflators are quoted in the currency of their country. For countries not listed on Eurostat (Norway, Switzerland, New Zealand, USA, Australia, Canada, Chile and China), the OECD total producer price index for all industrial activities (from the Producer Prices dataset) is used. For other countries (Portugal, Turkey, Russia, Korea, Japan), the domestic PPI for manufacturing retrieved from the St. Louis FRED database is used. For missing countries, GDP deflators are calculated based on data from the UN national accountrs. The GDP deflator is constructed based on nominal GDP data measured at current prices in national currency and real GDP measured at constant 2005 prices in national currency.

[50]See http://pub.stat.ee/px-web.2001/I_Databas/Economy/databasetree.asp.. Sectors are defined at the section level (e.g. 'C' is Manufacturing. The quarterly data in series 'WST21' has been transformed to annual data using a log-linear average.

[51]I ignore, for simplicity, other regressors from this regression.

My discussion has pointed out that the effective firm exchange rate for exports, $E^i_{X,t}$, should differ across firms, depending on whether they can adjust their price or not:

$$d\log E^i_X = \begin{cases} \left(\sum_{n\in\mathbb{X}^i}\frac{y^i_n}{y^i}d\log E_z\right) - \left(\sum_{n\in\mathbb{X}^i}\frac{y^i_\$}{y^i}d\log E_\$\right) \equiv d\log E^i_z - d\log E^i_\$ & \text{if} \quad i\in\Theta \\ \sum_{n\in\mathbb{X}^i}\frac{y^i_n}{y^i}\left(d\log E_z\right) \equiv d\log E^i_z & \text{if} \quad i\in\bar{\Theta} \end{cases}$$

But in my empirical analysis, I use the same effective exchange rate for all firms (see equations (I.9)):

$$d\log \bar{E}^i_X = d\log E^i_z - \theta d\log E_\$$$

where, here, I make explicit that this is an *expected* exchange rate across both types of firms by adding an upper bar.

Theorem 1. *The OLS estimator of β in the regression*

$$d\log y^i_t = \beta d\log \bar{E}^i_{X,t} + \varepsilon^i_t. \tag{III.14}$$

is a consistent estimator of $-\psi$, that means $plim\left(\hat{\beta}\right) = -\psi$, under the assumptions

$$plim\left(\frac{\left(d\log \bar{E}_X\right)'\left(d\log \bar{E}_X\right)}{N}\right) = Q,$$
$$plim\left(\frac{\left(d\log \bar{E}_X\right)'\left(d\log \bar{E}_\$\right)}{N}\right) = M,$$
$$plim\left(\frac{\left(d\log \bar{E}_X\right)'\left(\varepsilon\right)}{N}\right) = 0,$$

where M and Q are positive and finite.

Proof. Denote the two subsamples of firms with sticky and flexible prices by a superscript 1 and

2. The estimates of β from a regression (III.14) on either sample are

$$\hat{\beta}^1 = \left[\left(d\log \bar{E}_X^1\right)'\left(d\log \bar{E}_X^1\right)\right]^{-1}\left(d\log \bar{E}_X^1\right)'\left(-\psi\left(d\log \bar{E}_X^1 - (1-\theta)d\log E_\$^1\right) + \varepsilon^1\right)$$
$$\hat{\beta}^2 = \left[\left(d\log \bar{E}_X^2\right)'\left(d\log \bar{E}_X^2\right)\right]^{-1}\left(d\log \bar{E}_X^2\right)'\left(-\psi\left(d\log \bar{E}_X^2 + \theta d\log E_\$^2\right) + \varepsilon^2\right),$$

where I used the fact that I can rewrite the regression in (III.13) as

$$d\log y_t^i = \psi\left(d\log \bar{E}_{X,t}^i - (1-\theta)d\log E_{\$,t}^i\right) + \varepsilon_t^i \qquad \text{if} \quad i \in \Theta$$
$$d\log y_t^i = \psi\left(d\log \bar{E}_{X,t}^i + \theta d\log E_{\$,t}^i\right) + \varepsilon_t^i \qquad \text{if} \quad i \in \bar{\Theta}.$$

The probability limits of the estimators are

$$plim\left(\hat{\beta}^1\right) = -\psi - (1-\theta)\psi\frac{M}{Q}$$
$$plim\left(\hat{\beta}^2\right) = -\psi + \theta\psi\frac{M}{Q},$$

using Slutsky's theorem on probability limits. Running regression (III.14) on the entire sample gives an estimator

$$\begin{aligned}
\hat{\beta} &= \left[\left(d\log \bar{E}_X\right)'\left(d\log \bar{E}_X\right)\right]^{-1}\left(d\log \bar{E}_X\right)'\left(\begin{bmatrix} -\psi\left(d\log \bar{E}_X^1 - (1-\theta)d\log E_\$^1\right) \\ -\psi\left(d\log \bar{E}_X^2 + \theta d\log E_\$^2\right)\end{bmatrix} + \varepsilon\right) \\
&= \left[\left(d\log \bar{E}_X\right)'\left(d\log \bar{E}_X\right)\right]^{-1}\left(d\log \bar{E}_X^1\right)'\left(-\psi\left(d\log \bar{E}_X^1 - (1-\theta)d\log E_\$^1\right)\right) \\
&+ \left[\left(d\log \bar{E}_X\right)'\left(d\log \bar{E}_X\right)\right]^{-1}\left(d\log \bar{E}_X^2\right)'\left(-\psi\left(d\log \bar{E}_X^2 + \theta d\log E_\$^2\right)\right) \\
&+ \left[\left(d\log \bar{E}_X\right)'\left(d\log \bar{E}_X\right)\right]^{-1}\varepsilon \\
&= \left[\left(d\log \bar{E}_X\right)'\left(d\log \bar{E}_X\right)\right]^{-1}\left[\left(d\log \bar{E}_X^1\right)'\left(d\log \bar{E}_X^1\right)\hat{\beta}^1 + \left(d\log \bar{E}_X^2\right)'\left(d\log \bar{E}_X^2\right)\hat{\beta}^2\right].
\end{aligned}$$

Its probability limit is

$$
\begin{aligned}
plim\left(\hat{\beta}\right) &= \theta plim\left(\left[\frac{\left(d\log\bar{E}_X\right)'\left(d\log\bar{E}_X\right)}{n}\right]^{-1}\frac{\left(d\log\bar{E}_X^1\right)'\left(d\log\bar{E}_X^1\right)}{\theta n}\right)plim\left(\hat{\beta}^1\right) \\
&+(1-\theta)plim\left(\left[\frac{\left(d\log\bar{E}_X\right)'\left(d\log\bar{E}_X\right)}{n}\right]^{-1}\frac{\left(d\log\bar{E}_X^2\right)'\left(d\log\bar{E}_X^2\right)}{(1-\theta)n}\right)plim\left(\hat{\beta}^2\right) \\
&= \theta plim\left(\hat{\beta}^1\right)+(1-\theta)plim\left(\hat{\beta}^2\right) \\
&= \theta\left(-\psi-(1-\theta)\psi\frac{M}{Q}\right)+(1-\theta)\left(-\psi+\theta\psi\frac{M}{Q}\right) \\
&= -\psi. \qquad \square
\end{aligned}
$$

More information on the firm-level dataset

Datasets My firm-level data is provided by Statistics Estonia, a government agency that publishes official statistics on the Estonian economy. My analysis is based on two datasets. The first dataset has extensive trade data collected through the Extrastat and Intrastat system. Extrastat data are based on customs declarations for trade with non-EU countries, while Intrastat data for within-EU trade is based on statistical declarations and mainly misses small trade flows. The reporting thresholds for Intrastat in 2014 were annual imports of €130,000 and exports of €200,000. This trade data contains information on both imports and exports by product (CN 8-digit level) and firm, the partner country, the invoicing currency, the value in euros and the invoicing currency, and the net weight. Exports include goods originating from Estonia and goods from third countries.

The second dataset contains financial data of enterprises, which were collected on the basis of the annual statistical questionnaire "EKOMAR". The EKOMAR survey collects data on employment and hours worked, opening and closing balance sheets, income statements and capital expenditure. The survey population is based on the register of economically active enterprises. The population includes all firms with either positive revenue or at least one person employed

Table A.1: Firm-Year Observations per Sector

	Total	25,846
B	Mining and quarrying	259
C	Manufacturing	10,458
D	Electricity, gas, steam and air conditioning supply	134
E	Water collection, treatment and supply	237
F	Construction	1,293
G	Wholesale and retail trade; repair of motor vehicles	8,790
H	Transportation and storage	1,706
I	Accommodation and food service activities	261
J	Information and communication	879
L	Real eastate activities	143
M	Professional-, scientific and technical activity	753
N	Administrative and support service activities	408
P	Education	74
Q	Human health and social work activities	133
R	Arts, entertainment and recreation	158
S	Other service activities	160

The table displays the number of firm-year observations per sector for all years (2004 - 2012).

in the commercial register. The statistical unit is the enterprise as a company, including public limited companies, private limited companies and branches of foreign companies with 20 or more persons employed. All companies of private ownership with 20 or more persons employed are completely enumerated (although some companies might fail to return survey responses), whereas smaller companies are sampled. Every year a new sample of smaller firms is drawn, using stratified random sampling. The population is stratified by economic activity, by number of persons employed and by type of owner.

I merge these two datasets using a firm's tax ID as a common identifier. Not all trade data can be matched because some trade is done by government agencies, private persons and foreign firms that are not registered in Estonia.

Table A.1 displays the number of firm-year observations in my matched sample by sector. Most observations correspond to firms in the manufacturing or the wholesale / retail trade sector.

Dependent variables. My three main dependent variables at the firm level are gross output, intermediate consumption and hours worked. I use the term 'gross output' instead of revenue because my firm-level measure differs from revenue in several respects and its construction, in principle, is closely related to gross output at the national level. In particular, gross output subtracts the cost of merchandise from revenue, which is particularly important for firms in the wholesale and retail sector. In addition, it adjusts for changes in inventories and subtracts payments to subcontractors. Intermediate consumption includes both consumption of goods and services, and can be broken down into purchases of materials, supplies and intermediate goods, purchases of fuel and power, long-term rental and other laid-out work. Note that this definition includes rented capital services, but excludes capital services of purchased capital goods.

Table A.2: Effect of Exchange Rates on Firm Performance: Continuing Exporters and Importers

	Gross output $\Delta\log(p_t^i y_t^i)$			Intermediate consumption $\Delta\log(v_t^i q_t^i)$			Hours worked $\Delta\log l_t^i$		
	All (1)	Small (2)	Large (3)	All (4)	Small (5)	Large (6)	All (7)	Small (8)	Large (9)
$\Delta\log E_{X,t}^i$	1.027***	0.676	2.025***	1.125***	−1.040*	−1.592***	−0.385*	−0.325	−0.674***
	(0.372)	(0.518)	(0.463)	(0.386)	(0.549)	(0.448)	(0.225)	(0.327)	(0.257)
$(1-\gamma^i)\Delta\log E_{M,t}^i$	0.076	0.704	−1.659*	0.049	0.063	−0.657	−0.485	0.019	−1.399***
	(0.629)	(0.933)	(0.969)	(0.583)	(0.821)	(1.017)	(0.353)	(0.425)	(0.524)
$\gamma^I\Delta\log W_t$	0.568	0.969*	−0.430	0.333	0.66	−0.706	0.053	−0.248	−0.028
	(0.364)	(0.514)	(0.482)	(0.403)	(0.538)	(0.603)	(0.233)	(0.343)	(0.291)
$(1-\gamma^i)\Delta\log v_{z,t}^i$	0.33	0.423	−0.189	0.321	0.282	0.032	−0.474*	−0.156	−1.264***
	(0.398)	(0.491)	(0.500)	(0.387)	(0.451)	(0.559)	(0.242)	(0.286)	(0.337)
$\Delta\log D_{y,n,t}$	1.379***	1.724***	1.197***	0.38	0.59	0.340	0.081	0.01	0.09
	(0.289)	(0.394)	(0.357)	(0.345)	(0.427)	(0.410)	(0.213)	(0.325)	(0.229)
$\Delta\log D_{p,n,t}$	0.254	0.591	−0.077	0.316	0.567	0.043	0.036	−0.083	0.25
	(0.372)	(0.538)	(0.456)	(0.391)	(0.491)	(0.474)	(0.255)	(0.349)	(0.281)
$\Delta\log E_{\$,t}^i$	0.858	1.657*∗	−0.271						
	(0.640)	(0.821)	(0.913)						
Fixed effects:			(0.531)						
$\delta_t + \delta^i$	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	10,303	5,962	4,341	10,310	5,968	4,342	10,267	5,924	4,343
R^2	0.416	0.475	0.443	0.346	0.396	0.371	0.393	0.448	0.448

Notes: See Table I.4. Only contains firms with continuous exports and imports.

Appendix B Model

Steady state

I focus on a steady state with balanced trade. I choose the price of the domestic good to be the numeraire $\left(p^d = 1\right)$. I also adjust the desired price for imports in dollars such that $\frac{p^m E}{E_\$} = 1$. The investment FOC gives $\nu^j = U_1$ for all j. Utilization is $u^j = 1$, so that $a(u^j) = 0$. Then, from the capital Euler equations I have

$$\frac{R^j}{P} = \frac{1}{\beta} - (1 - \delta),$$

which implies that the rental price is equal across sectors: $R^j = R$. The optimal price setting equation gives the price in sector j as the marginal cost times the markup:

$$p^j = \mu MC^j,$$

where $\mu = \frac{\upsilon}{\upsilon - 1}$ is the markup. Then, the optimal choice of k^j requires that the rental price of capital equals the marginal product of capital, reduced by the inverse of the markup

$$\frac{1}{\beta} - (1 - \delta) = \frac{p^j}{P} \frac{\alpha \gamma y^j}{\mu K^j}.$$

I choose Z^d so that aggregate gross output, $Y = 1$. I then adjust Z^x so that $p^x = 1$ in steady state. It follows that $P = 1$. From the demand for domestic goods, this gives $y^d = \omega$ and $y^m = y^x = 1 - \omega$. From the optimal demand for intermediate goods, I can find Q^j:

$$Q^j = \frac{1 - \gamma}{\mu} y^j$$

Next, I adjust the labor disutility weight κ so that $\left(\frac{R}{\alpha}\right)^{\alpha}\left(\frac{W}{1-\alpha}\right)^{1-\alpha} = 1$. Then, optimal factor employment requires

$$\begin{aligned} D^j &= \frac{\gamma}{1-\gamma} Q^j \\ &= \frac{\gamma}{\mu} y^j. \end{aligned}$$

Inserting this into the expression for capital above gives K^j

$$RK^j = \frac{\alpha\gamma}{\mu} y^j$$

And L^j directly follows from the optimal capital-labor ratio:

$$WL^j = \frac{(1-\alpha)\gamma}{\mu} y^j.$$

Total investment and total intermediate consumption are

$$\begin{aligned} X &= \delta\left(K^d + K^x\right) \\ Q &= Q^d + Q^x. \end{aligned}$$

The market clearing condition for the final good allows me to find C

$$\begin{aligned} Y &= C + X + Q \\ C &= Y - (X + Q). \end{aligned}$$

To recover the productivity levels, I use the real marginal cost equation to get $Z^j = \mu$.

Appendix C Quantitative Analysis

Data sources for aggregate data

Data for impulse responses My main data sources are Eurostat and Statistics Estonia.[52]

- Real GDP, real consumption, real investment, net exports over GDP: Eurostat: National accounts (ESA 2010), Quarterly national accounts, Main GDP aggregates, GDP and main components [namq_10_gdp], seasonally adjusted and adjusted data by working days; Chain-linked volume (in 2005 Euros); real GDP: Gross domestic product at market prices (B1GQ), real consumption: Household and NPISH final consumption expenditure (P31_S14_S15), real investment: gross capital formation (P5G), net exports over GDP: (Exports of goods and services (P6) - Imports of goods and services (P7))/B1GQ ; Real GDP, real consumption and real investment are detrended using the estimated trend growth rate g_t

$$y_t^{detr} = \log y_t - \left(\log y_{ss} + \sum_{s=1}^{t-1} \log(1 + g_{s+1}) \right)$$

  for y being real GDP, real consumption or real investment, and where g_t is the trend growth rate of GDP per capita (see its estimation in the next section) and lower-case letters denote per capita variables.

$$nx_t^{detr} = \frac{ex_t - im_t}{gdp_t}$$

- Hours worked: Statistics Estonia: National accounts, Auxiliary indicators to national accounts, Employment by domestic concept by economic activity (NAL0011), Total, seasonally adjusted and adjusted data by working days

$$l_t^{detr} = \log l_t - \log l_{ss}$$

[52] See http://ec.europa.eu/eurostat/data/database and http://pub.stat.ee/px-web.2001/I_Databas/Economy/databasetree.asp.

- Inflation: Calculation based on harmonized index of consumer prices (CPI), Eurostat: Prices, HICP (2005 = 100) - monthly data (index) [prc_hicp_midx], Overall index excluding energy, food, alcohol and tobacco; monthly data log-linear averaged to quarterly data by author

$$\pi_t^{detr} = \log CPI_t - \log CPI_{t-4} - \pi_{ss},$$

  where π_{ss} is inflation in the first quarter of 2002.

- Wage inflation: Calculation based on total labor cost index (LCI), sectors B-S: Industry, construction and services, time series WST21, seasonally adjusted and adjusted data by working days

$$\pi_t^{w,detr} = \log LCI_t - \log LCI_{t-4} - \sum_{s=1}^{4} \log(1 + g_{t-s}) - \pi_{ss}^w,$$

  where π_{ss}^w is wage inflation in the first quarter of 2002.

- Population: Eurostat: Population and Social Conditions, Population on 1 January by age and sex [demo_pjan]; annual data log-linearly interpoplated to quarterly data by author

Data for calculating trend growth To calculate the trend growth rate (see section 'Data de-trending'), I use data from twelve European countries, in addition to Estonian data. EU-12 is composed of Belgium, Denmark, Germany, Ireland, Spain, France, Italy, Luxembourg, Netherlands, Austria, Portugal and Finland.

- Real GDP: OECD quarterly national accounts, seasonally adjusted; Unit: Millions of US dollars, volume estimates, fixed PPPs, OECD reference year, annual levels

- Population: Eurostat: Population and Social Conditions, Population on 1 January by age and sex [demo_pjan]; annual data log-linearly interpoplated to quarterly data by author

Data detrending

I estimate a trend growth rate in a two-step procedure. I allow for a time-varying growth rate to reflect an economic catch-up process. One of the goals of the EU is economic cohesion across all member states (see Single European Act, Article 158), which is typically interpreted as reducing disparities in GDP per capita. Between 1995 and 2014, Estonia indeed increased its GDP per capita from 30% to more than 60% of the EU average. I therefore assume that Estonia's growth rate consists of two parts: a constant growth rate that is identical to the EU growth rate, and a time-varying part that depends on the log difference between (predicted) EU-12 GDP per capita and Estonia's GDP per capita:

$$\ln gdp_t - \ln gdp_{t-1} - \hat{\bar{g}} = \gamma \left(\widehat{\ln gdp^{EU}_{t-1}} - \ln gdp_{t-1} \right) + \epsilon^g_t,$$

where I assume that the EU-12 growth rate is constant over time. I recover it as a log-linear trend of its GDP per capita:

$$\ln gdp^{EU}_t = \beta_0 + \bar{g}t + \epsilon^{g^{EU}}_t.$$

A positive γ gives rise to a catch-up process. In that case, Estonia's GDP per capita will converge to the EU average as t goes against infinity. I detrend Estonia's data by the estimated growth rate $g_t = \hat{\bar{g}} + \hat{\gamma} \left(\widehat{\ln gdp^{EU}_{t-1}} - \widehat{\ln gdp_{t-1}} \right)$, and I set $\widehat{\ln gdp_1} = \ln gdp_1$, where the first period corresponds to the first quarter of 1996.

I estimate both regressions using annual data from Eurostat over the years 1995 to 2014. The estimated growth rate for EU-12 is an annual 1%. Figure C.2 displays Estonia's estimated trend growth rate as well as the estimated trend and actual data.

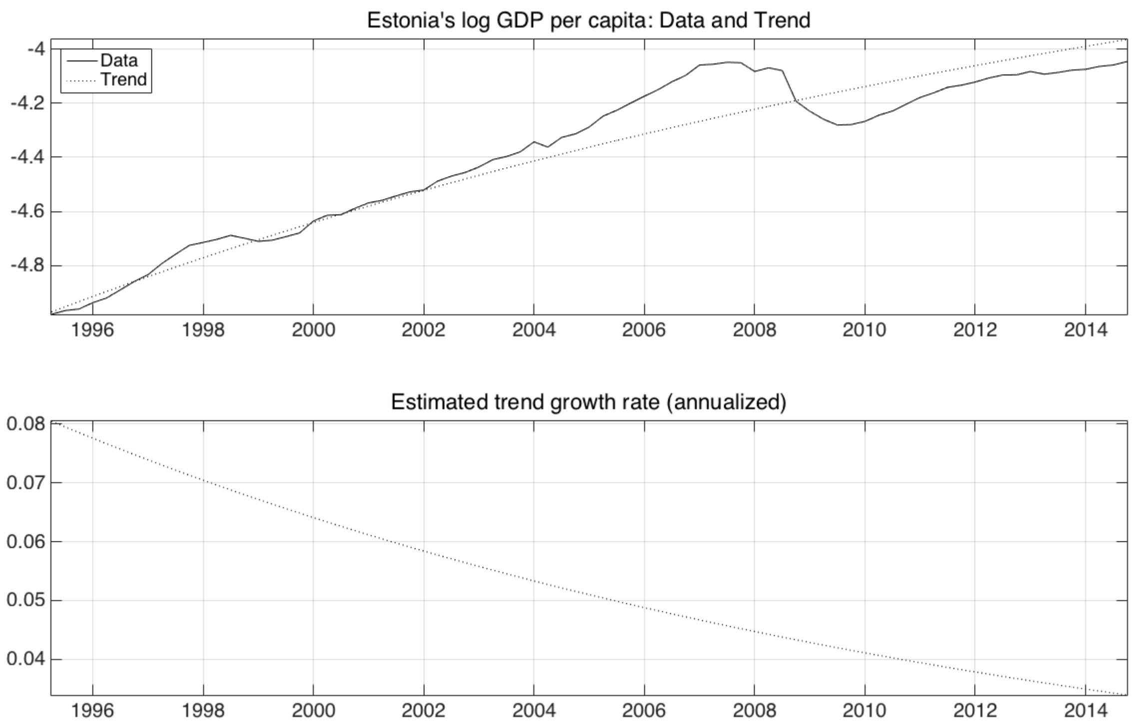


Figure C.2: Estonia's GDP per Capita: Trend and Growth Rate

Appendix D Additional Tables

Table D.1: Average Deviations from Trend

	Govt. Purch.		Tot. Outlays		Tot. Revenue		Prim. Bal.		GDP	
	Gov_1	Gov_2	TO_1	TO_2	TR_1	TR_2	PB_1	PB_2	GDP_1	GDP_2
Belgium	14.5	5.6	13.3	5.9	−3.4	12.8	−5.3	−3.5	−10.0	−12.6
Bulgaria	−0.1	−31.3	31.4	−18.2	−26.8	−9.5	−7.3	−2.2	−16.4	−17.2
Czech Republic	−36.1	−36.7	−24.6	−20.4	−14.0	−5.3	4.3	1.9	−12.7	−22.2
Denmark	4.2	−1.7	−6.7	−7.9	−4.2	3.8	−2.7	−1.7	−10.0	−16.3
Germany	12.8	11.4	4.3	0.9	5.5	3.4	1.6	1.1	−3.5	−2.5
Estonia	9.4	−2.7	3.8	−4.9	26.6	30.7	0.8	5.0	−12.3	−40.6
Ireland	−14.2	−22.6	−5.9	−11.7	−2.9	−9.1	−11.3	−8.2	−12.4	−45.4
Greece	−13.1	−31.0	−6.5	−20.1	−22.4	−11.1	−3.3	3.4	−35.3	−40.8
Spain	−17.3	−19.1	−0.1	−1.9	−6.9	−14.5	−9.5	−2.8	−22.0	−25.6
France	−0.9	−4.7	0.9	−2.7	−0.3	7.0	−1.9	−0.3	−11.8	−11.4
Italy	−0.5	−18.4	1.5	−13.7	7.4	39.4	0.8	7.3	−22.2	−18.8
Cyprus	−30.8	−33.5	−41.7	−36.5	−12.4	−11.5	−4.1	1.7	−24.2	−28.5
Latvia	−9.3	−26.7	3.7	−11.5	17.7	31.9	4.9	4.9	−10.8	−52.4
Lithuania	15.5	0.4	21.9	3.4	4.6	15.0	−8.6	−2.0	−3.9	−30.4
Luxembourg	−15.5	−27.5	−12.4	−25.3	−11.8	−9.9	1.2	3.5	1.8	−25.8
Hungary	−20.7	−41.3	−12.7	−47.6	−7.0	11.6	3.8	7.7	−25.9	−31.2
Netherlands	17.3	9.4	15.5	10.3	−1.8	10.3	−3.4	−2.2	−6.1	−14.9
Austria	7.8	6.1	2.7	4.5	−3.1	7.0	−0.4	4.0	−5.4	−10.1
Poland	7.8	8.2	6.7	1.3	7.9	9.3	−0.4	0.9	−4.7	6.7
Portugal	−10.2	−44.8	−3.9	−37.1	−6.0	3.6	1.6	4.0	−24.2	−21.4
Romania	10.9	−30.2	7.2	−11.6	11.4	18.8	−2.6	−1.5	−15.1	−23.5
Slovenia	4.3	−18.0	9.4	−17.1	−10.7	−0.1	−7.2	−2.3	−15.8	−22.3
Slovak Republic	1.5	16.1	3.8	17.2	6.7	5.5	−3.8	−2.3	−0.6	0.6
Finland	−0.3	−5.2	−3.2	−0.4	−11.6	−5.7	−4.0	−0.6	−10.9	−13.9
Sweden	1.7	4.9	−5.5	−0.6	−4.2	2.5	−2.0	−0.5	−4.6	−8.7
United Kingdom	11.4	−6.6	−1.0	−8.7	−6.8	14.8	−4.7	−3.0	−13.0	−18.5
Norway	6.1	−9.2	−1.8	−12.1	−2.5	−6.0	3.1	13.9	−1.6	−19.6
Switzerland	−3.4	0.5	−3.8	−2.2	−9.6	−9.1	−0.3	0.5	2.4	−0.1
United States	7.8	−2.8	6.9	−2.1	−0.8	3.6	−4.8	−3.5	−7.5	−14.7

Notes: Table displays the log-difference ($\times 100$) between the actual time series and the forecast, averaged over 2010 - 2014, for government purchases (Gov), total government outlays (TO), total government revenue (TR), the primary balance (PB) and GDP. For primary balance, the percentage point difference is displayed. The first column for each government finance variable reports values based on the shrinkage estimator; the second column reports values based on calibrated elasticities (see text for details). For the primary balance, the estimation regression does not include lagged primary balance in the case of the calibrated elasticity. The table also displays the forecast errors for GDP using either the 'convergence' estimator (column 1) or the 'shrinkage' estimator (column 2).

Table D.2: Austerity and GDP under Alternative Forecast and Trend Specifications

	Government Purchases (Shortfall)											
	Gov_1						Gov_2					
	All countries		Fixed		Floating		All countries		Fixed		Floating	
	β_1	R^2	β_1	R^2	β_1	R^2	β_1	R^2	β_1	R^2	β_1	R^2
Convergence	−0.30	0.21	−0.37	0.27	−0.20	0.15	−0.35	0.47	−0.35	0.45	−0.37	0.64
	(0.11)		(0.14)		(0.18)		(0.07)		(0.09)		(0.10)	
Shrinkage	−0.39	0.15	−0.48	0.19	−0.27	0.13	−0.48	0.38	−0.46	0.33	−0.55	0.72
	(0.18)		(0.23)		(0.26)		(0.12)		(0.15)		(0.13)	

	Total Outlays (Shortfall)											
	TO_1						TO_2					
	All countries		Fixed		Floating		All countries		Fixed		Floating	
	β_1	R^2	β_1	R^2	β_1	R^2	β_1	R^2	β_1	R^2	β_1	R^2
Convergence	−0.17	0.07	−0.19	0.09	−0.25	0.10	−0.38	0.38	−0.37	0.35	−0.46	0.68
	(0.12)		(0.14)		(0.29)		(0.09)		(0.12)		(0.12)	
Shrinkage	−0.19	0.03	−0.19	0.04	−0.46	0.16	−0.45	0.23	−0.42	0.19	−0.61	0.60

	(0.19)		(0.22)		(0.40)		(0.16)		(0.20)		(0.19)	

	Total Revenue											
	TR_1						TR_2					
	All countries		Fixed		Floating		All countries		Fixed		Floating	
	β_1	R^2	β_1	R^2	β_1	R^2	β_1	R^2	β_1	R^2	β_1	R^2
Convergence	0.24	0.09	0.28	0.14	0.02	0.00	0.00	0.00	0.10	0.03	−0.55	0.42
	(0.15)		(0.16)		(0.40)		(0.13)		(0.14)		(0.25)	
Shrinkage	−0.10	0.01	−0.17	0.02	0.31	0.04	−0.14	0.02	−0.10	0.01	−0.34	0.08
	(0.24)		(0.26)		(0.55)		(0.19)		(0.21)		(0.44)	

	Primary Balance											
	PB_1						PB_2					
	All countries		Fixed		Floating		All countries		Fixed		Floating	
	β_1	R^2	β_1	R^2	β_1	R^2	β_1	R^2	β_1	R^2	β_1	R^2
Convergence	0.21	0.01	0.26	0.01	−0.47	0.04	−0.22	0.01	−0.53	0.05	−0.03	0.00
	(0.41)		(0.51)		(0.90)		(0.39)		(0.56)		(0.57)	
Shrinkage	0.13	0.00	0.09	0.00	−0.98	0.08	−0.43	0.02	−0.51	0.02	−0.65	0.09
	(0.63)		(0.77)		(1.24)		(0.60)		(0.86)		(0.77)	

Notes: Table displays coefficients from regressing deviations of government finance variables on deviations of GDP deviation. Deviations are averaged over 2010 - 2014. Government finance variables are predicted either using a time trend and GDP or a time trend, GDP and a lag. GDP is predicted using either convergence, hugging or shrinkage estimators. Reported standard errors in parentheses are (untreated) OLS errors.

Table D.3a: Austerity and Economic Performance: Total Outlays (Shortfall)

	Total Outlays (Shortfall)					
	All countries		Fixed XRT		Floating XRT	
	α_1	R^2	α_1	R^2	α_1	R^2
GDP	-0.51	0.07	-0.56	0.09	-0.81	0.13
	(0.37)		(0.43)		(0.79)	
Inflation	0.07	0.03	0.08	0.06	0.02	0.00
	(0.07)		(0.07)		(0.20)	
Consumption	-0.31	0.02	0.00	0.00	-2.03	0.26
	(0.43)		(0.36)		(1.28)	
Investment	-0.31	0.00	-0.55	0.01	-1.13	0.03
	(1.04)		(1.19)		(2.26)	
Net Exports	-0.05	0.00	-0.15	0.01	0.50	0.23
	(0.25)		(0.33)		(0.35)	
Exchange Rate	0.08	0.00	-0.17	0.02	1.42	0.13
	(0.40)		(0.29)		(1.37)	
GDP Growth	-0.10	0.05	-0.12	0.07	-0.09	0.07
	(0.08)		(0.11)		(0.12)	
Unemployment Rate	0.21	0.05	0.31	0.10	0.24	0.06
	(0.19)		(0.22)		(0.35)	

Table D.3b: Austerity and Economic Performance: Total Revenue

	Total Revenue					
	All countries		Fixed XRT		Floating XRT	
	α_1	R^2	α_1	R^2	α_1	R^2
GDP	0.72	0.08	0.79	0.12	0.28	0.01
	(0.46)		(0.51)		(1.23)	
Inflation	−0.04	0.01	0.01	0.00	−0.31	0.16
	(0.09)		(0.09)		(0.27)	
Consumption	0.32	0.01	0.18	0.01	1.14	0.04
	(0.54)		(0.42)		(2.13)	
Investment	0.86	0.02	1.08	0.03	−0.42	0.00
	(1.31)		(1.41)		(3.34)	
Net Exports	0.00	0.00	0.09	0.00	−0.48	0.10
	(0.32)		(0.39)		(0.55)	
Exchange Rate	−0.06	0.00	0.24	0.03	−1.70	0.09
	(0.50)		(0.34)		(2.04)	
GDP Growth	0.27	0.22	0.33	0.33	−0.11	0.05
	(0.10)		(0.11)		(0.17)	
Unemployment Rate	−0.34	0.07	−0.28	0.06	−0.69	0.25
	(0.23)		(0.27)		(0.46)	

Table D.3c: Austerity and Economic Performance: Primary Balance

	Primary Balance					
	All countries		Fixed XRT		Floating XRT	
	α_1	R^2	α_1	R^2	α_1	R^2
GDP	0.21	0.01	0.26	0.01	−0.47	0.04
	(0.41)		(0.51)		(0.90)	
Inflation	−0.00	0.00	−0.00	0.00	−0.04	0.01
	(0.08)		(0.08)		(0.22)	
Consumption	0.01	0.00	0.26	0.02	−1.61	0.14
	(0.47)		(0.39)		(1.49)	
Investment	1.30	0.05	1.12	0.04	−0.04	0.00
	(1.10)		(1.31)		(2.48)	
Net Exports	0.23	0.03	0.20	0.02	0.75	0.43
	(0.27)		(0.36)		(0.33)	
Exchange Rate	0.16	0.01	−0.22	0.02	2.15	0.26
	(0.43)		(0.32)		(1.37)	
GDP Growth	0.04	0.01	0.07	0.02	−0.13	0.13
	(0.09)		(0.13)		(0.12)	
Unemployment Rate	−0.45	0.17	−0.43	0.16	−0.18	0.03
	(0.19)		(0.24)		(0.38)	

Notes: Table displays the estimated coefficient on the government finance variable from regression (II.2) as well as its R^2. The column $\bar{m}$ reports the average implied multiplier, which is the coefficient estimate divided by the share of the government finance variable in GDP (displayed in Table **??**). All government variables are forecasted using time trend (not for the primary balance), GDP and an own lag. GDP and GDP growth are forecasted using the 'convergence' estimator. Inflation, net exports, exchange rates and unemployment are forecasted using unit root. Exchange rate is the nominal effective exchange rate. Reported standard errors in parentheses are (untreated) OLS errors.

Table D.4: Interest Rates and Spreads

	CB rate			Taylor deviation			Spread		
	04-07	08-09	10-14	04-07	08-09	10-14	04-07	08-09	10-14
Belgium	2.7	2.6	0.8	0.1	-0.1	1.8	1.6	1.9	1.6
Bulgaria	2.7	2.6	0.8	0.1	-0.1	1.8	7.9	8.5	7.8
Czech Republic	3.3	3.5	1.1	−1.3	-4.1	1.3	1.4	1.6	2.2
Denmark	2.9	3.1	0.6	0.1	-0.1	1.8	2.0	2.9	3.6
Germany	2.7	2.6	0.8	0.1	-0.1	1.8	2.4	2.3	2.5
Estonia	2.7	2.6	0.8	0.1	-0.1	1.8	2.3	3.5	3.0
Ireland	2.7	2.6	0.8	0.1	-0.1	1.8	2.3	2.7	3.6
Greece	2.7	2.6	0.8	0.1	-0.1	1.8	2.9	3.1	5.5
Spain	2.7	2.6	0.8	0.1	-0.1	1.8	1.7	2.5	3.8
France	2.7	2.6	0.8	0.1	-0.1	1.8	1.5	1.8	1.7
Italy	2.7	2.6	0.8	0.1	-0.1	1.8	1.9	2.1	3.2
Cyprus	4.7	2.6	0.8	0.1	-0.1	1.8	2.4	4.4	5.8
Latvia	4.4	5.3	2.5	0.1	-0.1	1.8	3.5	8.5	2.8
Lithuania	2.7	2.6	0.8	0.1	-0.1	1.8	3.2	5.9	4.3
Luxembourg	2.7	2.6	0.8	0.1	-0.1	1.8	1.8	1.7	1.6
Hungary	8.3	8.7	5.0	−0.4	2.2	4.3	2.6	3.1	3.2
Netherlands	2.7	2.6	0.8	0.1	-0.1	1.8	1.4	2.0	2.5
Austria	2.7	2.6	0.8	0.1	-0.1	1.8	1.4	1.6	1.6
Poland	4.9	4.7	3.5	−1.4	-6.5	−5.9	2.1	2.7	2.2
Portugal	2.7	2.6	0.8	0.1	-0.1	1.8	3.5	4.1	5.5
Romania	11.8	9.4	5.2	−1.0	-0.9	5.4	6.3	7.6	4.6
Slovenia	3.8	2.6	0.8	0.1	-0.1	1.8	2.5	3.7	4.8
Slovak Republic	4.1	2.6	0.8	0.1	-0.1	1.8	1.6	2.5	3.2
Finland	2.7	2.6	0.8	0.1	-0.1	1.8	1.5	1.6	2.1
Sweden	2.4	2.4	1.0	−2.3	-3.2	−1.8	1.5	1.6	2.3
United Kingdom	4.8	2.7	0.5	0.6	-0.7	−0.7	1.0	1.7	2.0
Norway	2.7	3.5	1.7	−1.1	-3.6	−2.6	2.0	2.4	2.7
Switzerland	1.5	1.2	-0.1	0.3	-2.8	−0.7	0.7	0.9	1.8
United States	3.6	1.0	0.1	−0.4	-0.9	0.4	1.8	2.1	2.3
Average	3.5	3.2	1.2	−0.1	-0.8	1.2	2.4	3.1	3.2

Notes: Table displays the average central bank interest rates (CB rate, in percent), the average central bank interest rate less the rate implied by a monetary policy rule (Taylor deviations, in percentage points) and the spread between lending rates to businesses and the central bank interest rate (Spread, in percentage points). Averages are taken over 2004 - 2007 and 2009 - 2014. See text for details on the monetary policy rule.

Appendix E Details on Convergence Estimator

This estimator is based on the conditional convergence hypothesis. We assume that countries in Europe converge to a common path for GDP per capita. This can be justified on basis of the Single European Act (Article 158), which foresees economic cohesion across all member states as a central goal of the EU. Economic cohesion is typically interpreted as reducing disparities in GDP per capita. This convergence process especially affects our forecasts for Central and Eastern European countries, which, after strong economic growth in the 90s and 2000s, have reduced the gap to Western European countries. For instance, between 1995 and 2014, Estonia increased its GDP per capita from 30% to more than 60% of the EU-12 average.

To implement this idea, we estimate a time-varying growth rate for all countries in our sample in a two-step procedure. The two steps break the growth rate into a constant part and a time-varying part. In a first step, we estimate a constant growth rate for twelve advanced European countries, called EU-12 (Belgium, Denmark, Germany, Ireland, Spain, France, Italy, Luxembourg, Austria, Netherlands, Portugal and Finland). This growth rate $\bar{g}$ is estimated on data from 1993:1 to 2005:4:

$$\ln GDP_t^{EU} = \beta_0 + \bar{g}t + \epsilon_t^{EU},$$

where GDP is GDP per capita. The estimate of $\bar{g}$ is 0.49 percent with a standard deviation of 0.01 percent, i.e. the average annual growth rate over this time period was about 2 percent. In a second step, we estimate the time-varying part of the growth rate. We assume that the time-varying part is a linear function of the log difference between the predicted EU-12 GDP per capita and a country's GDP per capita:

$$g_t^i = \bar{g} + \gamma \left(\ln \widehat{GDP}_{t-1}^{EU} - \ln GDP_{t-1}^i \right),$$

where $\ln \widehat{GDP}^{EU}_{t-1} = \hat{\beta}_0 + \hat{\bar{g}}(t-1)$. We estimate γ by regressing

$$\ln GDP^i_t - \ln GDP^i_{t-1} - \hat{\bar{g}} = \gamma \left(\ln \widehat{GDP}^{EU}_{t-1} - \ln GDP^i_{t-1} \right) + \epsilon^i_t.$$

We estimate a common γ for all countries in Central and Eastern Europe (Bulgaria, Czech Republic, Estonia, Greece, Cyprus, Latvia, Lithuania, Hungary, Poland, Romania and Slovenia, Slovak Republic) using 1993:1 (or earliest available data) to 2005:4 as our sample period. Our estimate of γ is 0.51 percent with a standard deviation of 0.05 percent. The positive γ indicates convergence.

Our forecast for country i's log GDP per capita at time t is

$$\begin{aligned}
\ln \widehat{GDP}^i_t &= \ln GDP^i_{t-1} + \hat{\bar{g}} + \hat{\gamma} \left(\ln \widehat{GDP}^{EU}_{t-1} - \ln GDP^i_{t-1} \right) \qquad \forall t \leq \text{2006:1} \\
\ln \widehat{GDP}^i_t &= \ln \widehat{GDP}^i_{t-1} + \hat{\bar{g}} + \hat{\gamma} \left(\ln \widehat{GDP}^{EU}_{t-1} - \ln \widehat{GDP}^i_{t-1} \right) \qquad \forall t > \text{2006:1}.
\end{aligned}$$

The estimated growth rate of country i's GDP per capita at time t is

$$\begin{aligned}
\hat{g}^i_t &= \hat{\bar{g}} + \hat{\gamma} \left(\ln \widehat{GDP}^{EU}_{t-1} - \ln GDP^i_{t-1} \right) \qquad \forall t \leq \text{2006:1} \\
\hat{g}^i_t &= \hat{\bar{g}} + \hat{\gamma} \left(\ln \widehat{GDP}^{EU}_{t-1} - \ln \widehat{GDP}^i_{t-1} \right) \qquad \forall t > \text{2006:1}.
\end{aligned}$$

We repeat this two-step procedure to forecast private consumption and total investment. The estimated values for $\bar{g}$ and γ are 0.45 (0.01) percent and 0.71 (0.06) percent for private consumption, and 0.67 (0.03) percent and 1.17 (0.22) percent for total investment.

Appendix F Government Spending Shocks

In our empirical section we estimate deviations for government finance variables from their forecasts constructed from annual data. In the quantitative analysis, we treat those deviations as shocks and feed them into our model. The model, however, is calibrated at quarterly frequency. We use the Chow-Lin method to transform our predicted annual government spending series to quarterly series. As auxiliary high-frequency indicators we solely rely on real, quarterly GDP. Adding quarterly unemployment rates would barely affect the resulting time-series and the estimated coefficients are most of the time statistically non-significant. We estimate the model with maximum likelihood. The government spending shocks that we feed into our model are then the deviations of actual quarterly government spending data from their predicted quarterly levels.

Appendix G Monetary Policy Rules

Specifications

Taylor rule

$$i_t = \pi_t + r + \phi_\pi \left(\pi_t - \pi^{tar}\right) + \phi_{GDP}\%GDP_t + \epsilon_t$$

where i_t is the nominal interest rate, r is the long-run real interest rate, π_t is inflation, π^{tar} is the inflation target, $\%GDP_t$ are percent deviations of real GDP from its trend (output gap), and ϵ_t is an error term. Inflation is measured using the GDP deflator. Interest rates, inflation and the unemployment rate are measured in annual percent.

In the original Taylor rule, the parameters are set to $r = 2$ and $\pi^{tar} = 2$, and the estimated coefficients are $\phi_\pi = 0.5$ and $\phi_{GDP} = 0.5$.

Ben Bernanke[53] suggests to use core inflation as a measure of π and sets $\phi_{GDP} = 1$.

Clarida, Gali and Gertler (1999) propose a generalized Taylor rule that allows for interest rate smoothing:[54]

$$i_t = \rho i_{t-1} + (1-\rho)\left[\pi_t + r + \phi_\pi \left(\pi_t - \pi^{tar}\right) + \phi_{GDP}\%GDP_t\right].$$

Their estimates are $\rho = 0.79$, $\phi_\pi = 1.15$ and $\phi_{GDP} = 0.93$. They don't provide an estimate for the intercept or r.

Mankiw rule

$$i_t = \phi + \phi_{\pi,u}(\pi_t - u_t) + \epsilon_t,$$

where i_t is the nominal interest rate, π_t is core inflation, u_t is unemployment, and ϵ_t is an error term. Mankiw estimates $\phi = 8.5$ and $\phi_{\pi,u} = 1.4$.

[53] see http://www.brookings.edu/blogs/ben-bernanke/posts/2015/04/28-taylor-rule-monetary-policy

[54] In addition, their rule depends on expected inflation and the expected output gap instead of contemporaneous inflation and output gap. Their β coefficient corresponds to $1 + \phi_\pi$ in our setup.

Estimation

For the US, we estimate three different rules: A simple Taylor, a generalized Taylor rule a la CGG, and a Mankiw rule. For the Euro area and all countries with floating exchange rates, we us the slope coefficients from the US regressions and estimate a new intercept. We always impose that inflation targets a rate of 2%.[55]

Taylor rule Starting from the generalized Taylor rule

$$i_t = \phi_i i_{t-1} + (1-\phi_i)\left[\pi_t + r + \phi_\pi\left(\pi_t - \pi^{tar}\right) + \phi_{GDP}\%GDP_t + \epsilon_t\right],$$

our estimation equation is

$$\frac{i_t - \phi_i i_{t-1}}{1-\phi_i} - \pi_t = \beta_0 + \beta_1\left(\pi_t - \pi^{tar}\right) + \beta_2\%GDP_t + \epsilon_t.$$

Our estimates for r, ϕ_π and ϕ_{GDP} are $\hat{\beta}_0$, $\hat{\beta}_1$ and $\hat{\beta}_2$. In our estimation approach, we set $\phi_i = 0$ for the original Taylor rule and $\phi_i = 0.79$ for the CGG specification.

When we only estimate the intercept, the estimation equation is

$$\frac{i_t - \phi_i i_{t-1}}{1-\phi_i} - \pi_t - \hat{\phi}_\pi\left(\pi_t - \pi^{tar}\right) - \hat{\phi}_{GDP}\%GDP_t = \beta_0 + \epsilon_t$$

Mankiw rule Our estimation equation for the Mankiw rule is

$$i_t = \beta_0 + \beta_1(\pi_t - u_t) + \epsilon_t.$$

Our estimates for ϕ and $\phi_{\pi,u}$ are $\hat{\beta}_0$ and $\hat{\beta}_1$.

[55] Unless we make further restrictions, we cannot estimate r and π^{tar} separately, so we fix one of the two parameters prior to the estimation. CGG assume that r equals its average value of their estimation period and then estimate π^{tar}. They do not report their estimate of r. Their estimate of π^{tar} is 3.56. Here, we us the alternative approach of fixing $\pi^{tar} = 2$ and estimate r for every specification, including the original CGG specification.

When we only estimate the intercept, the estimation equation is

$$i_t - \hat{\phi}_{\pi,u}(\pi_t - u_t) = \beta_0 + \epsilon_t.$$

Estimation periods

- US: 1985.1 - 2005.4
- Eurozone: 1999.2 - 2005.4
- Czech Republic: 2000.2 - 2005.4
- Hungary: 2002.2 - 2005.4
- Poland: 2002.2 - 2005.4
- Romania 2003.2 - 2005.4
- Sweden: 1994.3 - 2005.4
- UK: 1985.1 - 2005.4
- Norway: 1991.2 - 2005.4
- Switzerland: 1991 - 2005.4

Table G.5: US Monetary Policy Coefficients

Panel A: Taylor rules

	r	ϕ_{π}	ϕ_{GDP}	ρ
Taylor	2.00	0.50	0.50	0.00
	-	-	-	-
Bernanke	2.00	0.50	1.00	0.00
	-	-	-	-
Estimated Bernanke	2.88	0.39	0.75	0.00
	(0.18)	(0.14)	(0.10)	-
CGG	2.35	1.15	0.93	0.79
	(0.24)	-	-	-
Estimated CGG	2.98	0.22	1.08	0.79
	(0.29)	(0.23)	(0.15)	-

Panel B: Mankiw rule

	ϕ	$\phi_{\pi,u}$
Mankiw	8.50	1.40
	-	-
Estimated Mankiw	10.73	1.79
	(0.56)	(0.17)

Note: Every row displays the coefficients for a different estimation run on US data. Reported standard errors are (untreated) OLS errors. See text for estimation period.

Table G.6: Estimated Intercepts

	USA	ECB	CZE	HUN	POL	ROM	SWE	GBR	NOR	CHE
Bernanke	2.88	0.49	0.95	1.35	7.23	1.54	4.58	2.40	3.51	1.33
	(0.18)	(0.09)	(0.43)	(0.31)	(0.31)	(0.93)	(0.29)	(0.33)	(0.28)	(0.22)
CGG	2.35	0.07	0.16	0.28	6.91	-1.96	4.11	1.72	3.17	1.14
	(0.24)	(0.24)	(0.48)	(1.48)	(0.51)	(2.65)	(0.37)	(0.44)	(0.42)	(0.28)

Note: Coefficients are estimated intercepts for the Bernanke rule and the CGG rule. The intercept corresponds to the real interest rate, r. See text for estimation period.

Appendix H Spread Shocks

Our measure of financial shocks comes from data on spreads between lending rates and central bank interest rates. Data on interest rates on business loans mainly comes from the ECB, but has been complemented by additional sources. The ECB reports monthly interest rates for new business loans up to 1 year original maturity to non-financial corporations in domestic currency (e.g. MIR.M.AT.B.A2A.F.R.0.2240.EUR.N for Austria). For countries accessing the euro area over the sample period, we try to use loans in domestic currency up to the year they access the euro area, and then switch to loans in euros. For some countries (e.g. Bulgaria, Estonia, Cyprus, Malta, Slovak Republic, Sweden, UK, Norway and Switzerland) we used national bank data sources to append the data series (or replace them if missing). For a few countries, we used data from the Fixed Income Global Financial Database to append the data series. The list below indicates the specific series used for each country:[56]

- Czech Republic: Business loans up to 1 year (ILCZESTM)
- Poland: Corporate lending rate (ILPOLCM)
- Romania: Average lending rate (ILROUM)
- Switzerland: Mortgage lending rate (ILCHEM)

Finally, US data comes from the Federal Reserve Survey of Terms of Business Lending, where we use the weighted-average effective loan rate for all commercial and industry loans.

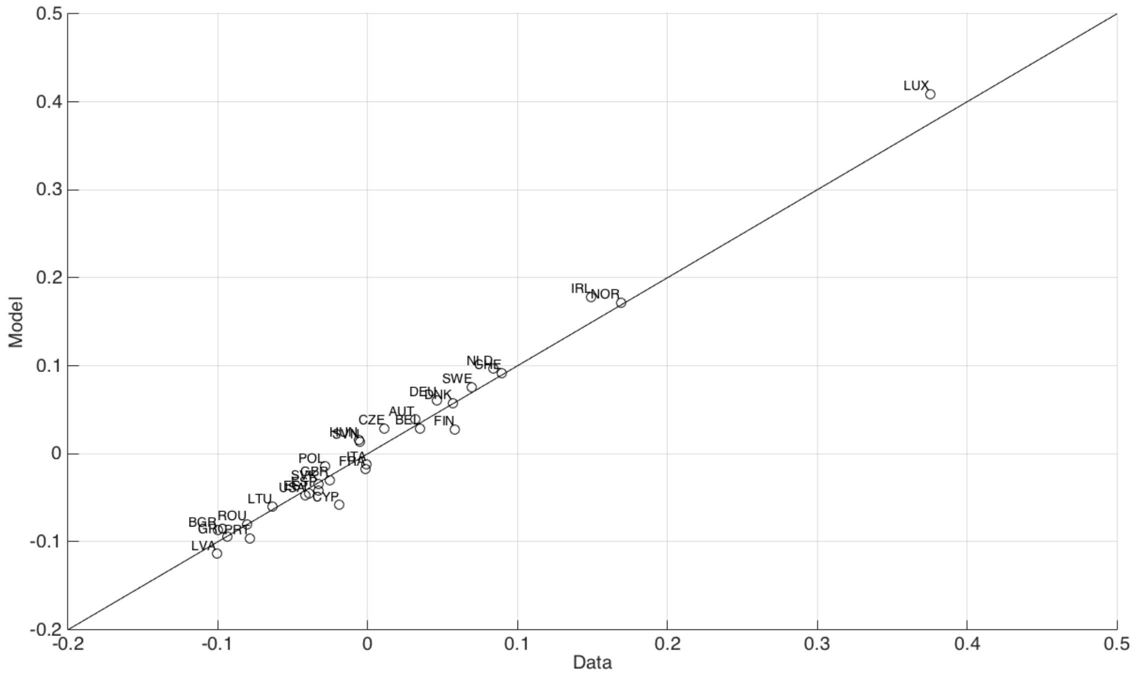
We use central bank interest rates to calculate the spread. For countries accessing the euro area over the sample period, we use the national central bank's interest rate up to the year they access the euro area.[57]

[56]We checked that the GFD data tracks reasonably well our preferred interest rate series for time periods with overlap.

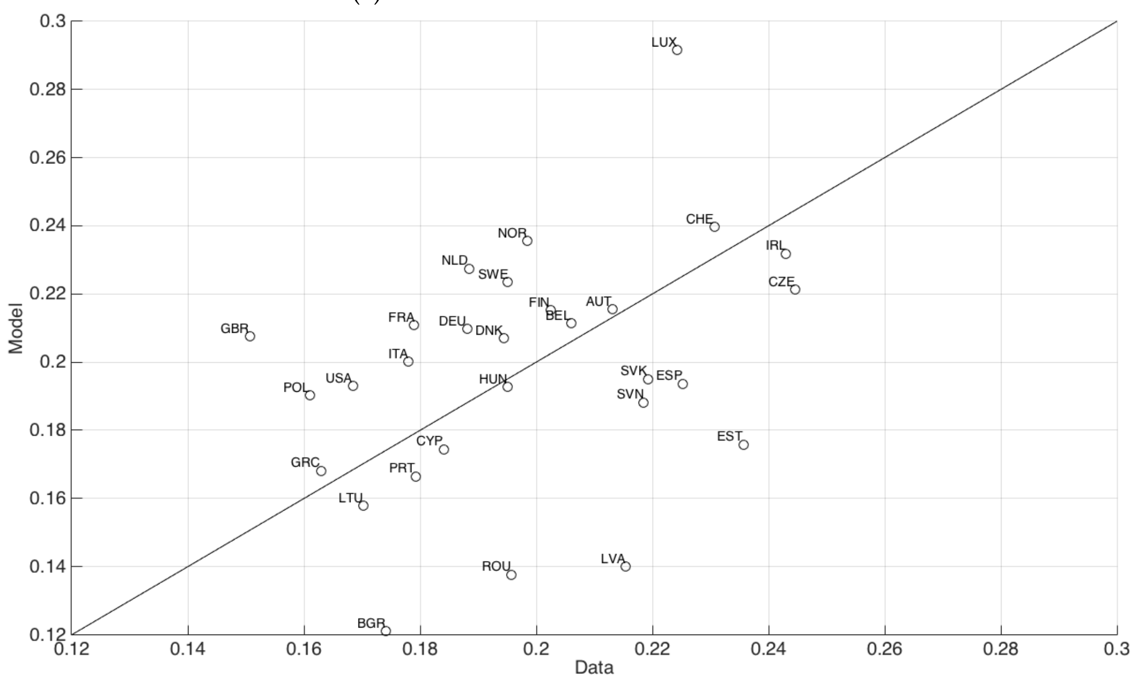
[57]In our model, we assign those countries directly to the euro area, ignoring the fact that in the beginning of the sample period they had an independent monetary policy.

Appendix I Calibration

Figure I.6 displays the non-target steady-state shares of net exports to final demand, NX_n/Y_n, and investment to final demand, X_n/Y_n. It compares the average shares observed in the data over 2000 - 2010 to the model-implied shares. The correlation between model and data is 0.99 for net exports. This is a surprisingly high correlation because the net export shares in the model are derived from parameters calibrated using data for 2005 and 2010 only: Net export shares in the model are functions of the trade preference parameters ω_n^j and relative country sizes $\mathbf{N}_n Y_n$, both of which are calibrated using input-output tables and the trade in value added database covering the years 2005 and 2010. The correlation between model and data for investment is substantially lower, but still positive: 0.36. Recall that the depreciation rate is calibrated so that the average investment shares in data and model match each other. Two features of the model create dispersion in investment shares: cross-country differences in net export positions NX_n/Y_n and in the external finance premium F_n. The figure suggests that the model underpredicts investment shares of countries in Central and Eastern Europe such Bulgaria, Romania and Latvia, but overpredicts investment shares of most advanced countries like Luxembourg, Norway and Great Britain. The high investment shares in Central and Eastern Europe could be rationalized by a catching up process towards the European core countries.



(a) Net Exports over Final Demand



(b) Investment over Final Demand

Figure I.6: Non-Targeted Steady-State Shares

Note: Table displays the non-target steady-state shares of net exports to final demand, NX_n/Y_n, and investment to final demand, X_n/Y_n. Data period is 2000 - 2010. The correlation between data and model is 0.99 for net exports and 0.36 for investment.

Appendix J Proofs of Propositions

Proposition 1. ***Sullying effect of crises on acquisitions by unconstrained firms***

Financial crises have a sullying effect on acquisitions by unconstrained firms in the sense that they lead to a lower average productivity of acquired firms, i.e., if $\tau_c < \tau_n$ *then* $\hat{A}^*_{in,c} < \hat{A}^*_{in,n}$.

Proof: To prove the proposition we show that the partial derivative of $\hat{A}^*_{in}$ with respect to τ is positive. $\hat{A}^*_{in}$ is a weighted sum of the average productivities of fire-sale and technology-driven acquisitions:

$$\hat{A}^*_{in} = \omega^*_{in}\hat{A}^{fire^*} + (1-\omega^*_{in})\hat{A}^{tech^*},$$

with $\omega^*_{in} = \frac{n^{fire^*}}{n^{fire^*}+n^{tech^*}}$ and

$$\begin{aligned}
\hat{A}^{fire^*} &= \frac{\int_{A^{fire^*}}^{A^{tech^*}} G\left(\frac{b}{\tau}\right) AdF^*}{\int_{A^{fire^*}}^{A^{tech^*}} G\left(\frac{b}{\tau}\right) dF^*} = \frac{\int_{A^{fire^*}}^{A^{tech^*}} AdF^*}{\int_{A^{fire^*}}^{A^{tech^*}} dF^*} \\
\hat{A}^{tech^*} &= \frac{\int_{A^{tech^*}}^{\bar{A}} AdF^*}{\int_{A^{tech^*}}^{\bar{A}} dF^*} \\
n^{fire^*} &= \int_{A^{fire}}^{A^{tech}} \int^{\frac{b}{\tau}} dGdF = G\left(\frac{b}{\tau}\right) \int_{A^{fire}}^{A^{tech}} dGdF \\
n^{tech^*} &= \int_{A^{tech}} dF.
\end{aligned}$$

The partial derivative is

$$\frac{\partial \hat{A}^*}{\partial \tau} = \frac{\partial \omega^*_{in}}{\partial \tau}\left(\hat{A}^{fire^*} - \hat{A}^{tech^*}\right) + \omega^*_{in}\frac{\partial \hat{A}^{fire^*}}{\partial \tau} + (1-\omega^*_{in})\frac{\partial \hat{A}^{tech^*}}{\partial \tau}$$

We simplify this expression step by step. Let $n^* = n^{fire^*} + n^{tech^*}$, then the partial derivative of the share of fire-sale acquisitions is:

$$\begin{aligned}\frac{\partial \omega_{in}^*}{\partial \tau} &= n^{*-2}\left(\frac{\partial n^{fire^*}}{\partial \tau} n^{tech^*} - \frac{\partial n^{tech^*}}{\partial \tau} n^{fire^*}\right) \\ &= -\frac{n^{tech^*}}{n^{*2}} \frac{b}{\tau^2} g\left(\frac{b}{\tau}\right) \int_{A^{fire}}^{A^{tech}} dF^* < 0.\end{aligned}$$

Note that both $\hat{A}^{fire^*}$ and $\hat{A}^{tech^*}$ are independent of τ. Taken together, the partial derivative of $\hat{A}_{in}^*$ equals:

$$\frac{\partial \hat{A}^*}{\partial \tau} = \frac{\partial \omega_{in}^*}{\partial \tau}\left(\hat{A}^{fire^*} - \hat{A}^{tech^*}\right) > 0,$$

where the inequality sign follows from $\frac{\partial \omega_{in}^*}{\partial \tau} < 0$ and $\hat{A}^{fire^*} < \hat{A}^{tech^*}$. ■

Proposition 2. ***Smaller acquired shares for unconstrained firms during crises***

Unconstrained firms acquire on average smaller shares during financial crises, i.e., if $\tau_c < \tau_n$ then $\hat{\alpha}_c^* < \hat{\alpha}_n^*$.

Proof: The proof follows the proof above, but replacing $\hat{A}^{fire^*}$ and $\hat{A}^{tech^*}$ with $\hat{\alpha}^{fire^*}$ and $\hat{\alpha}^{tech^*}$. The partial derivative of $\hat{\alpha}^*$ is

$$\frac{\partial \hat{\alpha}^*}{\partial \tau} = \frac{\partial \omega_{in}^*}{\partial \tau}\left(\hat{\alpha}^{fire^*} - \hat{\alpha}^{tech^*}\right) + \omega_{in}^* \frac{\partial \hat{\alpha}^{fire^*}}{\partial \tau} + (1 - \omega_{in}^*)\frac{\partial \hat{\alpha}^{tech^*}}{\partial \tau},$$

with

$$\hat{\alpha}^{fire^*} = \frac{\alpha^{fire^*}}{n^{fire^*}} \qquad \hat{\alpha}^{tech^*} = \frac{\alpha^{tech^*}}{n^{tech^*}}.$$

The average acquired share for fire-sale acquisitions is lower than the average acquired share for technology-driven acquisitions: $\hat{\alpha}^{fire^*} < \hat{\alpha}^{tech^*}$. This is the result of i) the positive dependence of the acquired share on the firm's permanent level of productivity, $\alpha'(A) > 0$ and ii) the lower productivity range for fire-sale acquisitions $A^{fire} \leq A < A^{tech}$ compared to technology-driven acquisitions $A \geq A^{tech}$. Then,

$$\frac{\partial \hat{\alpha}^*}{\partial \tau} = \frac{\partial \omega_{in}^*}{\partial \tau} \left(\hat{\alpha}^{fire^*} - \hat{\alpha}^{tech^*} \right) > 0,$$

where the inequality sign follows from $\frac{\partial \omega_{in}^*}{\partial \tau} < 0$ and $\hat{\alpha}^{fire^*} < \hat{\alpha}^{tech^*}$. ■

Proposition 3. ***No cleansing effect on domestic firms in absence of acquisitions***

In a model without any acquirers, financial crises do neither lead to a cleansing effect nor a sullying effect through the market for corporate control, i.e., if $\tau_c < \tau_n$ then $\hat{A}_{thru,c}^{noacq} = \hat{A}_{thru,n}^{noacq}$.

Proof: Proving the proposition requires taking the partial derivative of the average productivity with respect to the financial constraint parameter τ. Rewriting the average productivity

$$\hat{A}^{noacq} = \frac{\left(1 - G\left(\frac{b}{\tau}\right)\right) \int A dF}{\left(1 - G\left(\frac{b}{\tau}\right)\right) \int_{\underline{A}}^{\bar{A}} dF} = \int A dF$$

shows that it is independent of τ, so that the partial derivative with respect to τ is zero. ■

Proposition 4. ***Cleansing effect on domestic firms with unconstrained acquirers***

In a model with only unconstrained acquirers, financial crises lead to a cleansing effect through the market for corporate control, i.e., if $\tau_c < \tau_n$ then $\hat{A}_{thru,c}^* > \hat{A}_{thru,n}^*$.

Proof: We show that the partial derivative of $\hat{A}_{thru}^*$ with respect to τ is negative. The average productivity can be written as

$$\hat{A}_{thru}^* = \omega_{thru}^* \hat{A}^{ll^*} + (1 - \omega_{thru}^*) \hat{A}^{noacq},$$

where

$$\hat{A}^{ll^*} = \frac{A^{ll^*}}{n^{ll^*}} = \frac{\int_{A^{fire}} \int^{\frac{b}{\tau}} AdGdF}{\int_{A^{fire}} \int^{\frac{b}{\tau}} dGdF} = \frac{\int_{A^{fire}} AdF}{\int_{A^{fire}} dF}$$

and $\omega^*_{thru} = \frac{n^{ll^*}}{n^{ll^*}+n^{noacq}}$. Note that both average productivities $\hat{A}^{ll^*}$ and $\hat{A}^{noacq}$ are independent of τ. Then, taking the partial derivative with respect to τ gives:

$$\begin{aligned} \frac{\partial \hat{A}^{ll^*}}{\partial \tau} &= \frac{\partial \omega^*_{thru}}{\partial \tau} \left(\hat{A}^{ll^*} - \hat{A}^{noacq} \right) \\ &= \frac{\frac{\partial n^{ll^*}}{\partial \tau} n^{noacq} - n^{ll^*} \frac{\partial n^{noacq}}{\partial \tau}}{\left(n^{ll^*} + n^{noacq}\right)^2} \left(\hat{A}^{ll^*} - \hat{A}^{noacq} \right) < 0 \end{aligned}$$

because

$$\begin{aligned} \frac{\partial n^{ll^*}}{\partial \tau} &= -g\left(\frac{b}{\tau}\right) \frac{b}{\tau^2} \int_{A^{fire}} dF < 0 \\ \frac{\partial n^{noacq}}{\partial \tau} &= g\left(\frac{b}{\tau}\right) \frac{b}{\tau^2} \int dF > 0 \end{aligned}$$

and $\hat{A}^{ll^*} > \hat{A}^{noacq}$. ■

Proposition 5. ***Higher flipping rates for unconstrained acquirers***

Unconstrained acquisitions made during a financial crisis have higher flipping rates, i.e., if $\tau_1 = \tau_c < \tau_1 = \tau_n$ *then* $\frac{n_c^{flip^*}}{n_c} > \frac{n_n^{flip^*}}{n_n}$.

Proof: The proportion of flipped acquisitions by unconstrained acquirers is

$$\begin{aligned} \frac{n^{flip^*}}{n^*} &= \frac{n^{fire^*}}{n^{fire^*} + n^{tech^*}} \\ &= \omega^*_{in} \end{aligned}$$

In the proof for proposition 1, we have shown that $\frac{\partial \omega_{in}^*}{\partial \tau_1} < 0$. ■

Bibliography

Bibliography

Acharya, Viral, H. Song Shin, and Tanju Yorulmazer, "Fire-Sale FDI," *Korean Economic Review*, 2011, *27(2)*, 163–202.

Aguiar, Mark and Gita Gopinath, "Fire-Sale Foreign Direct Investment and Liquidity Crises," *Review of Economics and Statistics*, 2005, *87*, 439–452.

Almeida, Heitor, Murillo Campello, and Dirk Hackbarth, "Liquidity Mergers," *Journal of Financial Economics*, 2011, *102* (3), 526–558.

Alquist, Ron, Rahul Mukherjee, and Linda Tesar, "Liquidity-Driven FDI," 2015. RSIE Working Paper, No. 646.

_ , _ , and _ , "Fire Sale FDI or Business as Usual?," *Journal of International Economics*, 2016, *98*, 93–113.

Alvarez, Luis J, Emmanuel Dhyne, Marco Hoeberichts, Claudia Kwapil, Hervé Bihan, Patrick Lünnemann, Fernando Martins, Roberto Sabbatini, Harald Stahl, Philip Vermeulen et al., "Sticky Prices in the Euro Area: A Summary of New Micro Evidence," *Journal of the European Economic Association*, 2006, *4* (2-3), 575–584.

Amiti, Mary, Oleg Itskhoki, and Jozef Konings, "Importers, Exporters, and Exchange Rate Disconnect," *American Economic Review*, 2014, *104* (7), 1942–1978.

Arnold, Jens M. and Beata S. Javorcik, "Gifted Kids or Pushy Parents? Foreign Direct Investment and Plant Productivity in Indonesia," *Journal of International Economics*, 2009, *79* (1), 42–53.

Auerbach, Alan J. and Yuriy Gorodnichenko, "Output Spillovers from Fiscal Policy," 2012. NBER Working paper, No.18578.

Backus, David K., Patrick J. Kehoe, and Finn E. Kydland, "International Real Business Cycles," *Journal of Political Economy*, 1992, *100* (4), 745–775.

_ , _ , and _ , “Dynamics of the Trade Balance and the Terms of Trade: The J-Curve?,” *American Economic Review*, 1994, *84* (1), 84–103.

Barattieri, Alessandro, Susanto Basu, and Peter Gottschalk, “Some Evidence on the Importance of Sticky Wages,” *American Economic Journal: Macroeconomics*, 2014, *6* (1), 70–101.

Barro, Robert J. and Charles J. Redlick, “Macroeconomic Effects From Government Purchases and Taxes,” Technical Report 1 2009.

Barsky, Robert B., F. Thomas Juster, Miles S. Kimball, and Matthew D. Shapiro, “Preference Parameters and Behavioral Heterogeneity: An Experimental Approach in the Health and Retirement Study,” *Quarterly Journal of Economics*, 1997, *112* (2), 537–579.

Basu, Susanto and Christopher L. House, “Challenges for New Keynesian Models with Sticky Wages,” in John B. Taylor and Harald Uhlig, eds., *Handbook of Macroeconomics*, Vol. 2, Elsevier, 2016.

Bems, Rudolfs and Julian Di Giovanni, “Income-Induced Expenditure Switching,” 2014. CEPR Discussion Paper No. DP9887.

Berman, Nicolas, Philippe Martin, and Thierry Mayer, “How Do Different Exporters React to Exchange Rate Changes?,” *Quarterly Journal of Economics*, 2012, *127* (1), 437–492.

Bernanke, Ben and Mark Gertler, “Agency Costs, Net Worth, and Business Fluctuations,” *American Economic Review*, 1989, *79* (1), 14–31.

Bernanke, Ben S., Mark Gertler, and Simon Gilchrist, “The Financial Accelerator in a Quantitative Business Cycle Framework,” in John B. Taylor and Michael Woodford, eds., *Handbook of Macroeconomics*, Vol. 1, Elsevier, 1999, pp. 1341–1393.

Betts, Caroline and Michael B. Devereux, “The Exchange Rate in a Model of Pricing-Mo-Market,” *European Economic Review*, 1996, *40* (3), 1007–1021.

_ **and** _ , "Exchange Rate Dynamics in a Model of Pricing-To-Market," *Journal of international Economics*, 2000, *50* (1), 215–244.

Blalock, Garrick and Paul J. Gertler, "Welfare Gains from Foreign Direct Investment Through Technology Transfer to Local Suppliers," *Journal of International Economics*, 2008, *74* (2), 402–421.

Blanchard, Oliver and David Leigh, "Growth Forecast Errors and Fiscal Multipliers," *American Economic Review: Papers and Proceedings*, 2013, *103* (3), 117–120.

Blanchard, Olivier and Roberto Perotti, "An Empirical Characterization of the Dynamic Effects of Changes in Government Spending and Taxes on Output," *Quarterly Journal of Economics*, 2002, *117* (4), 1329–1368.

Brave, Scott A., Jeffrey R. Campbell, Jonas D. M. Fisher, and Alejandro Justiniano, "The Chicago Fed DSGE Model," 2012. Working Paper.

Broda, Christian, Joshua Greenfield, and David Weinstein, "From Groundnuts to Globalization: A Structural Estimate of Trade and Growth," 2006. NBER Working Paper No. 12512.

Brown, Craig O. and I. Serdar Dinc, "Too Many to Fail? Evidence of Regulatory Forbearance When the Banking Sector is Weak," *Review of Financial Studies*, 2011, *24* (4).

Buera, Francisco J., Joseph P. Kaboski, and Yongseok Shin, "Finance and Development: A Tale of Two Sectors," *American Economic Review*, 2011, *101* (5), 1964–2002.

Burstein, Ariel and Gita Gopinath, "International Prices and Exchange Rates," in Gita Gopinath, Elhanan Helpman, and Kenneth Rogoff, eds., *Handbook of International Economics*, Vol. 4, Elsevier, 2014.

_ **and** _ , "International Prices and Exchange Rates," in "Handbook of International Economics," Vol. 4, Elsevier, 2014.

Caballero, Ricardo J. and Mohamad L. Hammour, "On the Timing and Efficiency of Creative Destruction," *Quarterly Journal of Economics*, 1996, *111* (3), 805–52.

Campa, José M., "Exchange rates and trade: How important is hysteresis in trade?," *European Economic Review*, 2004, *48* (3), 527–548.

Campa, José M. and Linda S. Goldberg, "Investment in Manufacturing, Exchange Rates and External Exposure," *Journal of International Economics*, 1995, *38* (3), 297–320.

Campbell, John Y. and N. Gregory Mankiw, "Permanent and Transitory Components in Macroeconomic Fluctuations," 1987. Working Paper.

_ **and Pierre Perron**, "Pitfalls and Opportunities: What Macroeconomists Should Know About Unit Roots," in "NBER Macroeconomics Annual," Vol. 6, MIT press, 1991, pp. 141–220.

Carlstrom, Charles T. and Timothy Fuerst, "Agency Costs, Net Worth, and Business Fluctuations: A Computable General Equilibrium Analysis," *American Economic Review*, 1997, *87* (5), 893–910.

Céspedes, Luis F., Roberto Chang, and Andrés Velasco, "Balance Sheets and Exchange Rate Policy," *American Economic Review*, 2004, *94* (4), 1183–1193.

Chari, Anusha, Paige P. Ouimet, and Linda L. Tesar, "The Value of Control in Emerging Markets," *Review of Financial Studies*, 2010, *23* (4).

Chari, V.V., Patrick J. Kehoe, and Ellen R. McGrattan, "Sticky Price Models of the Business Cycle: Can the Contract Multiplier Solve the Persistence Problem?," *Econometrica*, 2000, *68* (5), 1151–1179.

Christiano, Lawrence J., Martin Eichenbaum, and Charles L. Evans, "Nominal Rigidities and the Dynamic Effects of a Shock to Monetary Policy," *Journal of Political Economy*, 2005, *113* (1), 1–45.

_ , **Roberto Motto, and Massimo Rostagno**, "Risk Shocks," *American Economic Review*, 2014, *104* (1), 27–65.

Clarida, Richard, Jordi Gali, and Mark Gertler, "The Science of Monetary Policy: A New Keynesian Perspective," *Journal of Economic Literature*, 1997, *37*, 1667–1707.

Cravino, Javier, "Exchange Rates, Aggregate Productivity and the Currency of Invoicing of International Trade," 2014.

Cui, Wei, "Delayed Capital Reallocation," 2014. Working Paper.

Dabušinskas, Aurelijus and Tairi Rõõm, "Survey Evidence on Wage and Price Setting in Estonia," Technical Report, Bank of Estonia 2011.

Dekle, Robert and Heajin H. Ryoo, "Exchange Rate Fluctuations, Financing Constraints, Hedging, and Exports: Evidence from Firm Level Data," *Journal of International Financial Markets, Institutions and Money*, 2007, *17* (5), 437–451.

Del Negro, Marco, Stefano Eusepi, Marc Giannoni, Argia Sbordone, Andrea Tambalotti, Matthew Cocci, Raiden Hasegawa, and M. Henry Linder, "The FRBNY DSGE Model," 2013. Federal Reserve Bank of New York Staff Report No. 647.

Devereux, Michael B. and Charles Engel, "Monetary Policy in the Open Economy Revisited: Price Setting and Exchange-Rate Flexibility," *Review of Economic Studies*, 2003, *70* (4), 765–783.

Di Giovanni, Julian, Andrei A. Levchenko, and Romain Ranciere, "Power Laws in Firm Size and Openness to Trade: Measurement and Implications," *Journal of International Economics*, 2011, *85* (1), 42–52.

Eisfeldt, Andrea L. and Adriano A. Rampini, "Capital Reallocation and Liquidity," *Journal of Monetary Economics*, 2006, *53* (3), 369–399.

Ekholm, Karolina, Andreas Moxnes, and Karen H. Ulltveit-Moe, "Manufacturing Restructuring and the Role of Real Exchange Rate Shocks," *Journal of International Economics*, 2012, *86* (1), 101–117.

Erceg, Christopher J, Dale W Henderson, and Andrew T Levin, "Optimal Monetary Policy with Staggered Wage and Price Contracts," *Journal of Monetary Economics*, 2000, *46* (2), 281–313.

Erel, Isil, Yeejin Jang, and Michael S. Weisbach, "Do Acquisitions Relieve Target Firms Financial Constraints?," *The Journal of Finance*, 2015, *70* (1).

Fitzgerald, Doireann and Stefanie Haller, "Exporters and Shocks: Dissecting the International Elasticity Puzzle," 2014. Working Paper No. 19968, National Bureau of Economic Research.

Foster, Lucia, John Haltiwanger, and Chad Syverson, "Reallocation, Firm Turnover, and Efficiency: Selection on Productivity or Profitability?," *American Economic Review*, 2008, *98* (1), 394–425.

Giorno, Claude, Pete Richardson, Deborah Roseveare, and Paul Van den Noord, "Estimating Potential Output, Output Gaps and Structural Budget Balances," *OECD Economic Studies*, 1995, *1* (24), 167–209.

Girouard, Nathalie and Christophe André, "Measuring Cyclically-Adjusted Budget Balances for OECD Countries," *OECD Economic Department Working Papers*, 2005, *434.*

Gopinath, Gita, "The International Price System," 2015. Working Paper No. 21646, National Bureau of Economic Research.

_ **and Oleg Itskhoki**, "In Search of Real Rigidities," in "NBER Macroeconomics Annual 2010," Vol. 25, Chicago: University of Chicago Press, 2011.

Gorodnichenko, Yuriy, Enrique G. Mendoza, and Linda L. Tesar, "The Finnish Great Depression: From Russia with Love," *American Economic Review*, 2012, *102* (4), 1619–1643.

Gourinchas, Pierre-Olivier, "Exchange Rates and Jobs: What Do We Learn From Job Flows?," in "NBER Macroeconomics Annual 1998," Vol. 13, MIT Press, 1999, pp. 153–222.

Hall, Robert E., "Sources and Mechanisms of Cyclical Fluctuations in the Labor Market," 2007. Manuscript, Stanford University.

Hall, Robert E, "By How Much Does GDP Rise If the Government Buys More Output?," Technical Report 2009.

Heathcote, Jonathan and Fabrizio Perri, "Financial Autarky and International Real Business Cycles," *Journal of Monetary Economics*, 2002, *49* (3), 601–627.

Holtz-Eakin, Douglas, David Joulfaian, and Harvey S. Rosen, "Sticking it Out: Entrepreneurial Survival and Liquidity Constraints," *Journal of Political Economy*, 1994, *102* (1), 53–75.

House, Christopher L., Christian Proebsting, and Linda L. Tesar, "Austerity in the Aftermath of the Great Recessions," 2015. Working Paper.

Kehoe, Timothy J. and Kim J. Ruhl, "Sudden Stops, Sectoral Reallocations, and the Real Exchange Rate," *Journal of Development Economics*, 2009, *89* (2), 235–249.

Kilian, Lutz and Lee E Ohanian, "Unit Roots, Trend Breaks, and Transitory Dynamics: A Macroeconomic Perspective," *Macroeconomic Dynamics*, 2002, *6* (05), 614–632.

Kim, Yoonbai and Yung-Hsiang Ying, "An Empirical Assessment of Currency Devaluation in East Asian Countries," *Journal of International Money and Finance*, 2007, *26* (2), 265–283.

Kim, Yun Jung, Linda L. Tesar, and Jing Zhang, "The Impact of Foreign Liabilities on Small Firms: Firm-Level Evidence from the Korean Crisis," *Journal of International Economics*, 2015, *97* (2), 209–230.

Kiyotaki, Nobuhiro and John Moore, "Credit Cycles," *Journal of Political Economy*, 1997, *105* (2), 211–248.

Klenow, Peter J. and Oleksiy Kryvtsov, "State-Dependent or Time-Dependent Pricing: Does It Matter for Recent US Inflation?," *Quarterly Journal of Economics*, 2008, *123* (3), 863–904.

Krugman, Paul, "Balance Sheets, the Transfer Problem, and Financial Crises," in "International Finance and Financial Crises," Springer, 1999, pp. 31–55.

Laeven, Luc and Fabián Valencia, "Resolution of Banking Crises: The Good, the Bad, and the Ugly," *IMF Working Paper*, 2010, *10/146.*

Moeller, Sara B., Frederik P. Schlingemann, and René M. Stulz, "Wealth Destruction on a Massive Scale? A Study of Acquiring-Firm Returns in the Recent Merger Wave," *The Journal of Finance*, 2005, *60*, 757–782.

Nakamura, Emi and Jón Steinsson, "Five Facts About Prices: A Reevaluation of Menu Cost Models," *Quarterly Journal of Economics*, 2008, *123* (4), 1415–1464.

Nelson, Charles R. and Charles R. Plosser, "Trends and Random Walks in Macroeconmic Time Series: Some Evidence and Implications," *Journal of Monetary Economics*, 1982, *10* (2), 139–162.

Oberfield, Ezra, "Productivity and Misallocation During a Crisis: Evidence from the Chilean Crisis of 1982," *Review of Economic Dynamics*, 2013, *16* (1), 100–119.

Osotimehin, Sophie and Francesco Pappadà, "Credit Frictions and the Cleansing Effect of Recessions," *The Economic Journal*, forthcoming.

Papke, Leslie E. and Jeffrey M. Wooldridge, "Econometric Methods for Fractional Response Variables With an Application to 401 (K) Plan Participation Rates," *Journal of Applied Econometrics*, 1996, *11* (6), 619–632.

Petersen, Mitchell A., "Estimating Standard Errors in Finance Panel Data Sets: Comparing Approaches," *Review of Financial Studies*, 2009, *22* (1).

Proebsting, Christian, "Are Devaluations Expansionary? - Firm-Level Evidence from Estonia," 2015. Working Paper.

Ramey, Valerie A. and Sarah Zubairy, "Government Spending Multipliers in Good Times and in Bad: Evidence from US Historical Data," 2014. NBER Working Paper, No.20719.

Reinhart, Carmen M. and Kenneth S. Rogoff, *This Time is Different: Eight Centuries of Financial Folly*, Princeton, N.J: Princeton University Press, 2009.

Rhodes-Kropf, Matthew and David T. Robinson, "The Market for Mergers and the Boundaries of the Firm," *The Journal of Finance*, 2008, *63* (3), 1169–1211.

Romer, Christine and David Romer, "A New Measure of Monetary Shocks: Derivation and Implications," *American Economic Review*, 2004, *94* (4), 1055–1084.

Rudebusch, Glenn D, "The Uncertain Unit Root in Real GNP," *The American Economic Review*, 1993, *83* (1), 264–272.

Sandleris, Guido and Mark L.J. Wright, "The Costs of Financial Crises: Resource Misallocation, Productivity, and Welfare in the 2001 Argentine Crisis," *The Scandinavian Journal of Economics*, 2014, *116* (1), 87–127.

Schmitt-Grohé, Stephanie and Martın Uribe, "Closing Small Open Economy Models," *Journal of International Economics*, 2003, *61* (1), 163–185.

Schumpeter, Joseph A., *Socialism, Capitalism and Democracy*, Harper and Brothers, 1942.

Smets, Frank and Rafael Wouters, "Shocks and Frictions in US Business Cycles: A Bayesian DSGE Approach," *American Economic Review*, 2007, *97* (3), 586–606.

Trabandt, Mathias and Harald Uhlig, "The Laffer Curve Revisited," *Journal of Monetary Economics*, 2011, *58* (4), 305–327.

UNCTAD, "World Investment Report 2015 - Reforming International Investment Governance," Technical Report 2015.

Wang, Jian and Xiao Wang, "Benefits of Foreign Ownership: Evidence from Foreign Direct Investment in China," *Journal of International Economics*, 2015, *97* (2), 325–338.

Woodford, Michael and Carl E. Walsh, *Interest and Prices: Foundations of a Theory of Monetary Policy*, Cambridge University Press, 2005.

Yasar, Mahmut and Catherine J. Morrison Paul, "International Linkages and Productivity at the Plant Level: Foreign Direct Investment, Exports, Imports and Licensing," *Journal of International Economics*, 2007, *71* (2), 373–388.