Essays on Macroeconomic Policies after the Global Financial Crisis

by

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DEDICATION

To my parents Lanmin Nie and Lixian Liu. Thank you for all of your love, support, and patience.

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ABSTRACT

The 2008-2009 global economic and financial crisis and its aftermath forced both academics and policymakers to rethink macroeconomics and macroeconomic policy. In particular, the crisis brought about intellectual shifts in how people think about capital account openness and the use of macro prudential policy/capital controls. This dissertation brings theoretical modeling, quantitative assessment and empirical evidence to bear on policy-relevant questions in international macroeconomics.

Following the crisis, capital controls have become standard policy tools in many emerging market economies. However, there is limited focus on what capital controls reveal about the state of the economy and the implications of such revelations. The first chapter of the dissertation focuses on what capital controls reveal about the state of the economy and the implications of such revelation for policy efficacy. Using a small open economy model with a collateral constraint and over-borrowing relative to the social optimum, I incorporate a representative agent's Bayesian updating of information in response to change in policy and show that the efficacy of capital controls to contain financial crises and improve welfare could be undermined if the agent rationally learns from policy. Empirically, the first chapter finds that capital controls convey important information market participants use to improve their understanding of fundamentals.

The second chapter shows that in a small open economy prone to self-fulfilling crisis, signaling of information about economic fundamentals through capital control policies enhances policy efficacy. Contrary to results stressed in the literature and in the first chapter, there exists equilibria with underborrowing in open-economy models because individual agents engage in excessive precautionary saving to self-insure. In this setting, capital controls can be more efficient at discouraging nonfundamental runs on the country's debt if they convey useful information about fundamentals, since the representative agent engages in less precautionary saving. Quantitatively, with signaling, the median capital control tax rate necessary to rule out equilibria with underborrowing is one third less than the median tax rate without signaling. Empirically, I construct a narrative list of Icelandic capital control policies between 2008 and 2017 and find that including capital controls in the forecaster's

information set helps improve her understanding of Icelandic economic fundamentals.

The Greek debt crisis in the aftermath of the crisis ignited renewed interest in the role of fiscal consolidation. The expansionary fiscal contraction (EFC) hypothesis states that fiscal austerity can increase output or consumption when a country is under heavy debt burdens because it sends positive signals about the country's solvency situation and long-term economic wellbeing. Empirical tests of this hypothesis have suffered from identification concerns due to data sources and empirical methodology. The third chapter uses new IMF narrative data and the proxy structural VAR methodology to examine whether fiscal austerity can be expansionary when debt levels are high enough. I define fiscal austerity as both narrative fiscal shocks and as structural shocks from a proxy SVAR. Additionally, I use a model-based approach to define the cutoff debt level beyond which EFC is expected to be observed. I find empirical evidence in support of the EFC hypothesis for output. My results are driven by changes in tax rates and are robust to how one defines a high-debt regime and how one measures austerity.

CHAPTER I

The Information Content of Capital Controls

1.1 Introduction

Capital controls, residency-based or currency-based measures used to regulate cross-country financial flows, are increasingly considered part of the standard financial stability policy tool-kit for many emerging market economies(EMEs). A widely-held view in the recent academic literature and in policy institutions is that national authorities can mitigate the effects of inefficient and destabilizing capital inflows by the active use of capital controls. However, as have been found for other types of macroeconomic policies, an announcement of policy changes conveys not only the action itself, but also information about the authorities' views on the state of the economy. Rational market participants can be expected to learn from policy announcements and adjust their behavior accordingly. Capital controls can convey invaluable information about economic fundamentals.[1] The current literature has paid limited attention to the information conveyed by capital controls and what this means for policy effectiveness.

This paper shows that capital controls convey useful information about economic fundamentals and this can dampen the effectiveness of capital controls in mitigating the effects of excessive capital inflows. I analyze a small open economy model in which agent borrows

[1] Paul Tucker, in the International Monetary Fund(IMF)'s third rethinking macroeconomic policy conference, neatly summarized the importance of understanding information revelation as follows: *Any macroprudential measures will reveal not only the action itself but also information about the authorities' views on the state of the financial system. In contrast to monetary policy, where the data on the economy are in the public domain, a prudential policymaker has lots of private information about vulnerabilities in individual financial institutions and the linkages among those institutions. If the market is surprised that the policymaker is concerned enough to act, credit conditions might tighten sharply if market participants conclude, on the basis of the information newly available to them, that the actions taken are insufficient. If, by contrast, the market has been ahead of the authorities in sporting a lurking threat to stability and so is relieved that the policymaker is finally waking up, credit conditions might even ease. There are many scenarios in-between.*

more than socially optimal and capital controls are deployed to address overborrowing. Contrary to previous research, the agent in this model learns from capital controls and updates their information set of economic fundamentals accordingly. I find that when people learn from policy, capital controls can lead to unintended consequences such as larger consumption drops and currency devaluations during a financial crisis. Moreover, welfare gains from policy may become negative. Empirically, I present evidence from Brazilian data that expectations of economic fundamentals respond to capital control announcements: first, the paper uses a high-frequency strategy to show that such announcements tend to affect daily forecasts of GDP collected by the Central Bank of Brazil; second, the paper constructs an econometric model to nowcast Brazilian GDP with real-time macroeconomic data, and shows that such announcements reduce the forecast errors of the model.

In the theoretical section, I incorporate learning from policy into a standard model researchers use to study capital controls in emerging market economies. In this two-sector small open economy model, borrowing by domestic agent is limited by tradable and nontradable income through a collateral constraint. This environment features a pecuniary externality because individual agents do not internalize the effect of their borrowing decisions on the value of collaterals and hence on borrowing capacity. Capital controls are usually deployed by the government to mitigate the effect of overborrowing by agents arising from the pecuniary externality. I incorporate three novel features in this setting to model learning from policy: first, the government knows more about future economic fundamentals than the representative agent. Second, the agent knows that the government is levying capital control taxes according to a simple policy rule which reveals useful information previously unknown to her. Last but not least, the agent learns from policy by completing a Bayesian updating of her information set when she observes policy changes.

A version of my model is calibrated to the Brazilian economy and the quantitative model features unintended consequences of capital controls when people learn from policy. I choose the Brazilian economy between 2006 and 2013 because the country experienced large and volatile capital inflows during the period and actively used capital controls to manage such inflows with some success. I solve the calibrated model for the decentralized equilibrium[2], the equilibrium with policy interventions but no learning from policy and most importantly, the equilibrium with both. When people learn from policy, the domestic economy borrows more from foreign countries and experiences more severe financial crisis in the sense of larger consumption drops, real exchange rate depreciations and capital outflows relative to the

[2] Equilibrium with no policy intervention

cases of no policy and no learning. This is because agents are less uncertain about the future and save less for precautionary reasons. When this mechanism is strong enough, imposing capital controls could result in welfare losses relative to the decentralized equilibrium.

The key assumption in my model is that people learn about economic fundamentals from capital controls. In the empirical section, I provide some evidence of this assumption from an event study of capital control announcements in Brazil and from an exercise nowcasting Brazilian real GDP. Event studies using high-frequency data show that expectation of economic fundamentals in Brazil respond meaningfully to major capital control announcements. Specifically, I use daily survey data of market participants' median expectation of quarterly real GDP growth collected by the Central Bank of Brazil and I consider six major capital control announcements in the country between 2008 and 2013. On average, a tightening(loosening) announcement is associated with a downward(upward) revision of real GDP growth forecast of 0.23%.

Since the survey data averages many forecasters' expectations constructed with different methodologies, and hence can be hard to interpret in greater details, I provide a second set of empirical evidence by taking a stand on how to form expectations of fundamentals. Specifically, I put myself in the position of a forecaster who employees a commonly-used econometric model and uses all types of available macroeconomic data to produce nowcasts[3] of Brazilian quarterly GDP growth rates in real-time. Including capital control announcements in the forecaster's information set helps improve the precision of her nowcast. The magnitude of such improvement measured in the nowcasting model provides a basis for the calibration of key model parameters related to Bayesian updating and learning in my quantitative model earlier.

Related literature This paper contributes to several strands of the international macroeconomics literature. First, it adds to the recent theoretical literature of macro-prudential policies and capital controls by incorporating signaling through and learning from such credit regulations. Academic and policy consensus prior to the global financial crisis(GFC) viewed restrictions to free financial flows across countries as almost undesirable as restrictions on free trade. The policy consensus has shifted in the wake of the GFC (see Ostry et al. (2010) and IMF Strategy, Policy and Review department (2011)), and the recent academic literature is now focused on better understanding the proper role of capital controls. A number of papers, including Mendoza (2010), Korinek and Jeanne (2010), Bianchi (2011), Korinek

[3] A nowcast is a forecast of the present or the very-near future when data have yet to be released.

(2011), Jeanne (2012), Brunnermeier and Sannikov (2014), Heathcoate and Perri (2016), among others, explore the role of macro-prudential interventions or restrictions on capital flows by introducing an externality of people not considering the effect of their actions on borrowing capacity. My paper builds on Bianchi (2011) and Bianchi, Mendoza and Liu (2016). In the former, uncertainties regarding economic fundamentals are present, but the representative agent does not attempt to reduce it. In the latter, the agent receives a noisy but useful signal about fundamentals to learn from. However, the signal is an exogenous state variable and hence the agent's information set does not change with respect to policy actions. My paper differs from both of these papers: the agent learns from policy actions and hence her information set changes with respect to policy.

Second, this paper also contributes to the empirical literature on capital controls. Instead of focusing on the efficacy (Edison and Rehinhart (2001), Forbes (2007), Edwards and Rigobon (2009), Magud, Reinhart and Rogoff (2011), Klein(2012), Forbes et al. (2015), Ben Zeev (2017), to name only a few) or unintended consequences ((Miniane and Rogers (2004), Forbes et al. (2016) among others)) of capital controls, I attempt to identify the empirical relationship between capital control announcements and expectations of fundamentals by looking at high-frequency survey data and by employing a nowcasting model, an empirical methodology new to this literature. Moreover, my model provides possible explanations for some empirical findings in this literature, such as these in Klein (2012) and Forbes et al. (2015).

Last but not least, this paper joins several earlier papers to explore signaling of and learning about fundamentals through macroeconomic policies in general. Most notably, Nakamura and Steinsson(2016) argue that people's belief about underlying economic fundamentals (the natural rate of interest) change with Federal Reserve announcements, and this information mechanism has important implications for the overall effectiveness of U.S. monetary policy, as it works against the traditional mechanism in a New Keynesian motenary model. Garcia-Schmidt (2015) considers information asymmetry between the government and a foreign lender in an equilibrium sovereign default model. When the foreign lender knows less about future output than the government, volatility of sovereign spreads increases substantially. My paper pursues a similar research agenda for a different kind of policy.

1.2 A model where agent learns from capital controls

In this section, I construct a two-sector small open economy model with three novel features to study the implications of learning from policy. The model features an occasionally binding collateral constraint which limits international borrowing, as in Bianchi (2011). There are three main points of departure from previous studies: 1) Asymmetric information between government and the representative agent: government knows more about economic fundamentals, and the agent knows that government knows more. 2) Government levies capital control taxes according to a simple policy rule which reveals its superior information of fundamentals. 3) The agent learns about fundamentals from capital controls by completing a Bayesian updating of her information set upon observing a policy action.

1.2.1 Representative agent's problem

Consider a representative agent DSGE model with a tradable goods sector and a nontradable goods sector. Tradable goods can be sold to foreigners and nontradable goods can only be consumed in the domestic economy. The economy is populated by a continuum of identical, infinitely-lived agents with preferences given by:

$$E_0 \Sigma_{t=0}^{\infty} \beta^t u(c_t) \tag{1.1}$$

$$c_t = [\omega (c_t^T)^{-\eta} + (1-\omega)(c_t^N)^{-\eta}]^{-\frac{1}{\eta}} \tag{1.2}$$

where β is the discount factor, the period utility function $u(.)$ has the constant-relative-risk-aversion(CRRA) form and c_t is a CES aggregator of tradable and nontradable goods with elasticity of substitution $\frac{1}{1+\eta}$. In each period, the agent receives an endowment of tradable goods y_t^T, which follows a first-order Markov process, and an endowment of nontradable goods y_t^N, which is normalized to 1 for convenience.

The only foreign financial asset available is a one-period, non state-contingent bond denominated in units of tradables. The bond pays an interest rate R_t, which follows an exogenous process driven by global liquidity conditions. This assumption is meant to capture the observation that emerging economies usually borrow in short-term debt denominated in foreign currency. In each period, the government levies a capital control tax τ_t on bond issued in the current period maturing in the next period. Tax revenue collected from the capital control tax is rebated to the agent as a lump-sum transfer, T_t.

In each period, the agent chooses tradable consumption, nontradable consumption and bond holdings to maximize the expected discounted sum of her utility, subject to equation 1.3, her budget constraint and equation 1.4, her collateral constraint:

$$(1+\tau_t)b_{t+1} + c_t^T + p_t^N c_t^N = b_t(1+R_t) + y_t^T + p_t^N y_t^N + T_t \tag{1.3}$$

$$b_{t+1} \geq -(\kappa^N p_t^N y_t^N + \kappa^T y_t^T) \tag{1.4}$$

where the price of tradables is normalized to 1. As in Bianchi(2011), the central externality of this model is introduced through the collateral constraint, which restricts the amount of debt to a fraction of the market value of the agent's tradable and nontradable endowment income[4]. This collateral constraint is usually perceived as arising from institutional or informational frictions which are not modeled explicitly. The first-order conditions with respect to c_t^T,c_t^N and b_{t+1} are given below:

$$\lambda_t = u_T(t) \tag{1.5}$$

$$p_t^N = (\frac{1-\omega}{\omega})(\frac{c_t^T}{c_t^N})^{\eta+1} \tag{1.6}$$

$$\lambda_t = \beta(1+R_t)(1+\tau_t)E_t\lambda_{t+1} + \mu_t \tag{1.7}$$

where λ_t and μ_t are Lagrangian multipliers of the budget constraint and the collateral constraint and they may be interpreted as the shadow value of wealth and the shadow benefit of relaxing the collateral constraint, respectively. $u_T(t)$ is the marginal utility of tradable consumption. Equation 1.5 equates the marginal utility of tradable consumption to the shadow value of wealth. Equation 1.6 equates the marginal rate of substitution between tradable and nontradable goods to their relative price. Equation 1.7 is the Euler equation for bonds: when the collateral constraint is binding, a wedge between the current and the future shadow value of wealth is given by μ_t, the shadow benefit of relaxing the collateral constraint.

The collateral constraint amplifies the negative income shock to the economy: when such a negative shock hits the domestic economy, agent wants to cut c_t^T to be able to borrow more. However, from equation 1.6, this causes a drop in p_t^N, the relative price of nontradables, which further tightens the right hand side of equation 1.4 and causes the borrowing capacity to decrease even more, exacerbating the effects of the negative income shock.

[4]As in the literature, the margin requirement is the same for tradable and nontradable endowments. There are reasons to believe that the margin requirement should be different, as nontradables are harder to seize in the event of default. Appendix A.D provides a more detailed discussion on this topic.

To complete the description of the representative agent's problem, the following complementary slackness conditions are also needed:

$$\mu_t \geq 0 \tag{1.8}$$

$$(b_{t+1} + (\kappa^N p_t^N y_t^N + \kappa^T y_t^T))\mu_t = 0 \tag{1.9}$$

Finally, markets for both tradable goods and nontradable goods clear:

$$c_t^N = y_t^N \tag{1.10}$$

$$b_{t+1} + c_t^T = b_t(1 + R_t) + y_t^T \tag{1.11}$$

Bianchi(2011) has shown that the Ramsey optimal capital control taxes a social planner uses to fully internalize the pecuniary externalities is given by:

$$\tau_t^* = \frac{E_t \mu_{t+1}^{sp} \Psi_{t+1}}{E_t u_T(t+1)} - \frac{\mu_t^{sp} \Psi_t}{\beta(1+r) E_t u_T(t+1)} \tag{1.12}$$

where $\Psi_t \equiv \frac{\kappa^N p_t^N c_t^N}{c_t^T (1+\eta)}$ indicates how much the collateral value changes at equilibrium when there is a change in tradable consumption.

1.2.2 Government and capital controls

The government has superior information about future economic fundamentals: it knows y_{t+1}^T at time t. I focus on tradable income because its realization drives the relative price of nontradables, the tightness of the collateral constraint and hence financial stability in this model. The assumption that the government knows more than the private agent is motivated by several considerations. First, the academic literature of the information content of U.S. monetary policy(Romer and Romer (2010) and Nakamura and Steinsson (2018)) assumes that the Federal Reserve possesses some knowledge of the economy that the private sector does not have. Second, the empirical section in this paper shows evidence that private forecasts of fundamentals responds to capital control announcements by the government. Lastly, the assumption is motivated by the observation that a capable regulator or policymaker, in general, possesses superior knowledge on information relevant to its regulatory responsibilities because it has the unique mandate of supervision and because the private sector sometimes does not think about the externalities of its actions[5]. Hence, I choose Brazil's experience with capital controls for my case study in the empirical section later on, hoping to get as close to the concept of a capable policymaker of capital controls as possible.

To mitigate the pecuniary externality arising from the collateral constraint, the government implements capital controls by taxing next period bond holdings of the agent. As in equation 1.7, the tax distorts the agent's intertemporal Euler's equation by making future borrowings more costly. I employ a policy rule of the capital control tax rate as a linear function of future states instead of using τ_t^*, the Ramsey optimal tax rates. The policy rule is preferred than Ramsey-optimal tax for my purposes for three reasons: first, as noted in other works, the optimal tax schedule varies across different states in a complicated way, so regulators may find it difficult to implement it in time to respond to an ongoing financial crisis. Second, this tax rule is quantitatively similar to an optimal tax in reducing the frequency and severity of a financial crisis and delivering welfare gains. Last but not least, this simple rule facilitates learning by the agent about economic fundamentals: an optimal state-contingent tax may prove hard or even impossible for the agent to extract information from. The policy rule is as follows:

$$\tau_t = \phi_0 + \phi_1 y_{t+1} + v_t \tag{1.13}$$

$$v_t = \alpha + \rho v_{t-1} + \epsilon_t \tag{1.14}$$

It consists of two components: the first component is related to next-period tradable income. Intuitively, if the government sees a lower future tradable income, this implies a lower tradable consumption allocation and hence a lower relative price of nontradables, so the collateral constraint is more likely to bind. In this case, the government sets a higher tax rate on borrowings to try to prevent the economy from hitting the collateral constraint. $\phi_1 < 0$ captures the procyclical nature of optimal capital control tax as shown in Schmitt-Grohe and Uribe(2017), and it is also consistent with evidence presented later in the empirical section

[5]A real world example is as follows: a financial regulator is charged with the mandate of maintaining financial stability. Hence, she accumulates knowledge and gains expertise through research in this subject area, information collection authorized by the law, on-site examination of financial institutions, stress tests and other activities. The regulator does not know more than a private sector firm about how to run its business, but she does knows more about the overall state of what it regulates, a point neatly summarized by Raghuram Rajan in one of his interviews: *FINANCE & DEVELOPMENT, March 2015, Vol. 52, No. 1: These are smart guys. They're from Goldman Sachs. They're from JPMorgan. They're paid a ton of money. They're the smartest kids in the room. Why would they blow up their business? And who are we, you know, low-paid regulators, thinking that we know more about their business than they do? And the answer is no, we dont know more about their business than they do, but we have different incentives. They're locked into this competitive frenzy. And we're the guys who can stop them.*

that GDP growth forecasts respond negatively to a tightening of capital controls. The second component of the policy rule is v_t, a random shock term which follows an AR(1) process. Its interpretation is analogous to that of an exogenous shock to a Taylor rule (Taylor (1993) and Christiano, Eichenbaum and Evans (1998)): the term can represent exogenous shocks to policymakers' preferences, measurement errors in policymakers' data or other shocks not related to the systematic responses to variations in the state of the economy. The shock term is uncorrelated with other state variables. The government knows both components and hence the tax rate τ_t, while the agent only observes τ_t, but cannot tell its components apart.

Figure 1.1 illustrates the policy rule for my benchmark calibration with three states (high, medium and low) for tradable incomes: when next-period tradable income is medium, the government imposes a baseline tax rate of 3.6% on bond holdings. When a high (low) future income is observed, it lowers (increases) the tax rate by 1.6% to 2.0% (5.2%). However, the government cannot set the exact tax rate it would like, because a random shock pushes the rate up or down by 0.8%. Hence, the agent observes four different tax rates in this setting. The magnitude of the random shock is a half of 1.6%, the absolute value of the difference between the baseline rate and the higher(lower) rate. This calibration ensures the agent does not have perfect information about future states after learning: for instance, the actual tax rate after a medium output realization and a positive shock equals the tax rate after a high output realization and a negative shock. What matters is that the agent learns something useful after observing the tax rates.

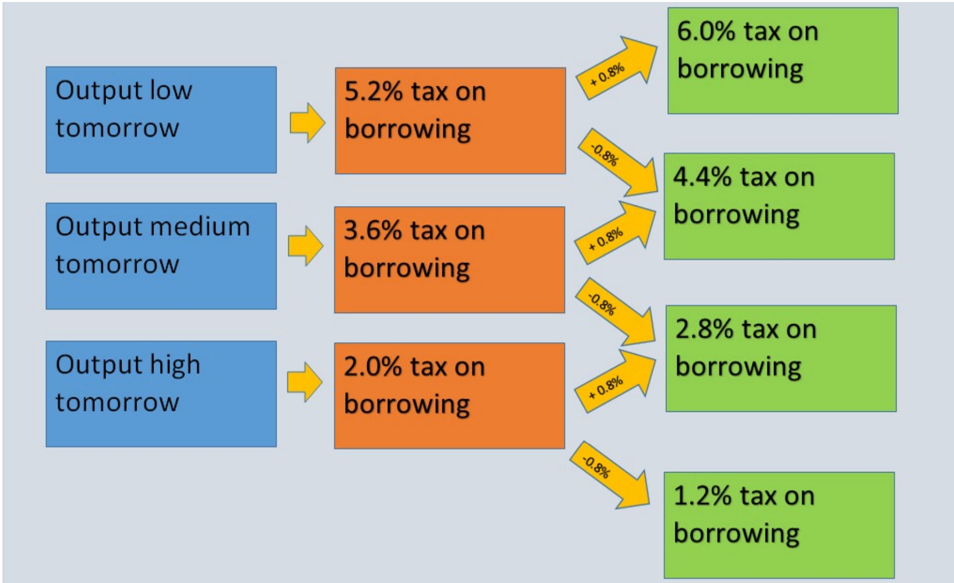
Finally, all tax revenue collected are rebated to the representative agent as a lump-sum transfer and the government budget balances in each period:

$$T_t = \tau_t b_{t+1} \tag{1.15}$$

1.2.3 Information structure

In this section, I describe the agent's information structure and how it changes with learning. Unlike the government, the agent does not observe tradable income one period ahead. This means the agent has incentives to learn from useful signals to improve her understanding of future tradable income. The agent learns from an exogenous signal, as in prior literature, and from capital control policy actions, a novel feature of this paper.

Figure 1.1: Simple rule for capital control tax rate



First, I describe the information structure prior to learning from policy: this is a benchmark of how much the agent knows without observing policy actions. The structure is proposed by Durdu et al.(2013) and used in Bianchi, Liu and Mendoza(2016), which I base my analysis on. The agent receives a noisy but useful signal about future tradable income. Each period, the signal s_t is realized after y_t^T. The agent makes use of the signal and tradable income this period to form expectation about next period tradable income according to the Bayes rule. The information updating process prior to observing capital controls is given by equation 1.16 to 1.20. The probability of a signal conditional on an income level is:

$$p(s_t = i | y_{t+1}^T = l) = \theta, i = l \tag{1.16}$$

$$p(s_t = i | y_{t+1}^T = l) = \frac{1-\theta}{N-1}, i \neq l \tag{1.17}$$

The agent forecasts next period tradable income conditional on current period information:

$$p(y_{t+1}^T = l | s_t = i, y_t^T = j) = \frac{p(s_t = i | y_{t+1}^T = l) p(y_{t+1}^T = l | y_t^T = j)}{\Sigma_n p(s_t = i | y_{t+1}^T = n) p(y_{t+1}^T = n | y_t^T = j)} \tag{1.18}$$

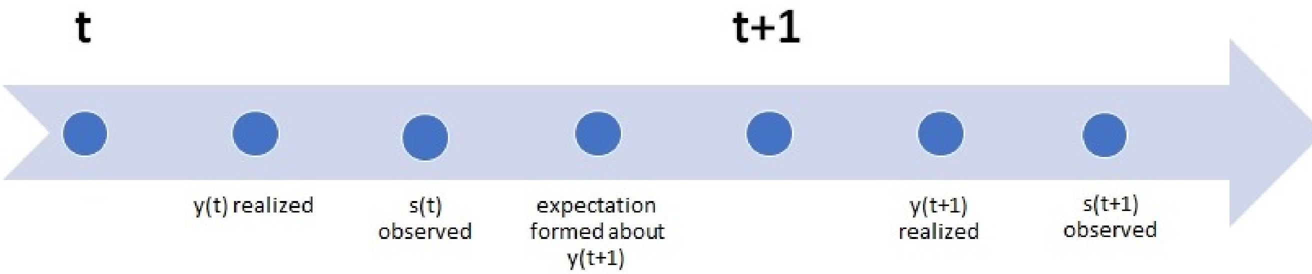
The Markov process of the joint evolution of tradable income and signal is given by:

$$\Pi(y_{t+1}^T, s_{t+1}, y_t^T, s_t) = p(|s_{t+1} = k, y_{t+1}^T = l | s_t = i, y_t^T = j) \tag{1.19}$$

$$= p(y_{t+1}^T = l | s_t = i, y_t^T = j) \Sigma_m p(s_{t+1} = k | y_{t+2}^T = m) p(y_{t+2}^T = m | y_{t+1}^T = l) \tag{1.20}$$

The timeline of the model prior to learning from policy is shown below:

Figure 1.2: Model timeline before observing capital controls



In this paper, the agent learns from policy itself in addition to learning from the exogenous signal. When the government levies capital control tax, the agent utilizes this information to help herself better understand economic fundamentals. She completes a Bayesian updating of the probability distribution of future tradable endowment when she observes a capital control tax, because she understands the government knows more and is revealing its knowledge through the policy rule. Although the agent cannot tell the deterministic and the random components of the tax rule apart, she knows the form of the policy rule and the value of parameters in the rule. Hence, her estimates of the likelihood of observing a certain tax rate conditioning on next period tradable income is:

$$p(\tau_t = k | y_{t+1}^T = l) = p(\phi y_{t+1}^T + v_t = k | y_{t+1}^T = l) = p(v_t = k - \phi l) \tag{1.21}$$

In this equation, the agent knows the underlying process for v_t, but she does not observe v_t directly. To extract useful information from capital controls, she must form an estimate of $p(\tau_t = k|y_{t+1}^T = l)$. The agent knows the random component of the tax rule last period, since $v_{t-1} = \tau_{t-1} - \phi_0 - \phi_1 y_t$ and both τ_{t-1} and y_t are observed this period. So her estimates involves keeping track of v_{t-1} and using it to form expectations:

$$p(v_t = k - \phi l) = p(\alpha + \rho v_{t-1} + \epsilon_t = k - \phi l) = p(\epsilon_t = k - \phi l - \alpha - \rho v_{t-1}) \tag{1.22}$$

Figure 1.1 helps illustrate equation 1.22: if the agent observes a tax rate of 6.0%, she knows this can only be the result of a low future income realization coupled with a positive random shock this period. However, if she observes a tax rate of 4.4%, one of the following two situations could be true: either future income is low and the random shock is low, or future income is medium and the random shock is high. The probabilities she assigns to these events are based on whether she thinks the random shock is high or low today, which are in turn based on whether it was high or low yesterday due to persistence of v_t.

Using the Bayes rule and the law of total probability, the agent's forecast of future tradable income conditional on a specific observed capital control tax rate is:

$$p(y^T_{t+1} = l|\tau_t = k) = \frac{p(\tau_t = k|y^T_{t+1} = l)p(y^T_{t+1} = l)}{\Sigma_n p(\tau_t = k|y^T_{t+1} = n)p(y^T_{t+1} = n)} \tag{1.23}$$

As discussed before, the agent knows y^T_t and s_t before observing capital controls. Her forecast of tradable income conditional on all information at time t is:

$$p(y^T_{t+1} = l|s_t = i, y^T_t = j, \tau_t = k) = \frac{p(\tau_t = k|y^T_{t+1} = l)p(y^T_{t+1} = l|s_t = i, y^T_t = j)}{\Sigma_n p(\tau_t = k|y^T_{t+1} = n)p(y^T_{t+1} = n|s_t = i, y^T_t = j)} \tag{1.24}$$

and hence the joint evolution of income and signal is given by:

$$p(y^T_{t+1} = l, s_{t+1} = m|s_t = i, y^T_t = j, \tau_t = k) = \tag{1.25}$$

$$\frac{p(\tau_t = k|y^T_{t+1} = l, s_{t+1} = m)p(y^T_{t+1} = l, s_{t+1} = m|s_t = i, y^T_t = j)}{\Sigma_{n,m} p(\tau_t = k|y^T_{t+1} = n, s_{t+1} = m)p(y^T_{t+1} = n, s_{t+1} = m|s_t = i, y^T_t = j)} \tag{1.26}$$

If the agent observes a capital control tax, the precision of her forecast regarding future tradable income increases. Finally, the joint evolution of income, signal and tax rate is given by:

$$p(y^T_{t+1} = l, s_{t+1} = m, \tau_{t+1} = n|s_t = i, y^T_t = j, \tau_t = k) = \tag{1.27}$$

$$p(\tau_{t+1} = n|y^T_{t+1} = l, s_{t+1} = m)p(y^T_{t+1} = l, s_{t+1} = m|s_t = i, y^T_t = j, \tau_t = k) \tag{1.28}$$

where

$$p(\tau_{t+1} = n|y^T_{t+1} = l, s_{t+1} = m) = \Sigma_k p(\tau_{t+1} = n|\tau_t = k)p(\tau_t = k|y^T_{t+1} = l, s_{t+1} = m) \tag{1.29}$$

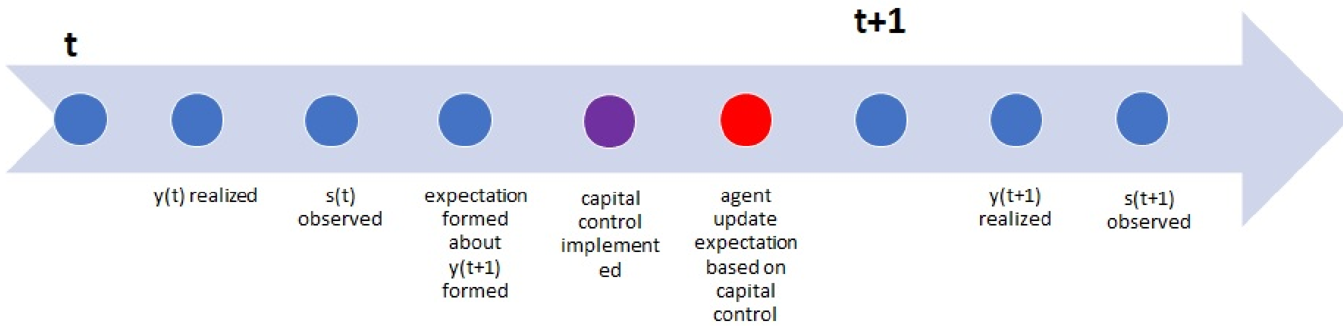
This joint process is then combined with the evolution of other exogenous state variables to form the entire transition probability matrix the agent uses to form expectations in her dynamic programming problem.

The timeline of the model with learning from policy is given by figure 1.3:

1.2.4 Equilibrium definition

I define three equilibria here: the decentralized equilibrium (denoted **DE**), where there is no policy intervention at all; the equilibrium with policy intervention through the capital

Figure 1.3: Model timeline with learning from policy



control policy rule but no learning from policy(denoted **P**); the equilibrium with both policy intervention and learning from policy (denoted **PL**).

Definition 1 defines a decentralized equilibrium in the domestic economy.

Definition 1. Given the state contingent processes y_t^T, s_t, R_t and given that $\tau_t = 0 \forall t$, **DE** is a sequence of price p_t^N and allocations b_{t+1}, c_t^T, c_t^N such that:
1. Agent maximizes her utility subject to the budget constraint and the collateral constraint, taking p_t^N as given.
2. Markets for tradable goods and nontradable goods clear.
3. Agent learns from the exogenous signal s_t to forecast future tradable income as in equations 1.16-1.20.

Definition 2 defines an equilibrium with policy intervention but no learning from policy.

Definition 2. Given the state contingent processes y_t^T, s_t, R_t, v_t and government policy τ_t, **P** is a sequence of price p_t^N and allocations b_{t+1}, c_t^T, c_t^N such that:
1. Agent maximizes her utility subject to the budget constraint and the collateral constraint, taking p_t^N and τ_t as given.
2. Government levies capital control tax τ_t according to equation 1.13.
3. Markets for tradable goods and nontradable goods clear.
4. Agent learns from the exogenous signal s_t to forecast future tradable income as in equations 1.16-1.20.

Definition 3 defines an equilibrium with both policy intervention and learning from policy.

Definition 3. Given the state contingent processes y_t^T, s_t, R_t, v_t and government policy τ_t, **PL** is a sequence of price p_t^N and allocations b_{t+1}, c_t^T, c_t^N such that:
1. Agent maximizes her utility subject to the budget constraint and the collateral constraint, taking p_t^N and τ_t as given.
2. Government levies capital control tax τ_t according to equation 1.13.
3. Markets for tradable goods and nontradable goods clear.
4. Agent learns from both the exogenous signal s_t and the capital control tax τ_t to forecast future tradable income as in equations 1.23-1.26.

The last equilibrium concept is the novelty of this paper. To see how this concept differs from equilibrium definitions in previous works, I write down the dynamic programming problem of the agent in recursive form, where state variables are collected in the vector $z_t = (y_t^T, s_t, R_t, \tau_t, v_{t-1})'$:

$$V_t(b_t, z_t) = \max_{c_t^T, c_t^N, b_{t+1}} [u([\omega(c_t^T)^{-\eta} + (1-\omega)(c_t^N)^{-\eta}]^{-\frac{1}{\eta}}) + \beta E_{z_{t+1}|z_t} V_{t+1}(b_{t+1}, z_{t+1})] \tag{1.30}$$

subject to

$$(1+\tau_t)b_{t+1} + c_t^T + p_t^N c_t^N = b_t(1+Rt) + y_t^T + p_t^N y_t^N + T_t \tag{1.31}$$

$$b_{t+1} \geq -(\kappa^N p_t^N y_t^N + \kappa^T y_t^T) \tag{1.32}$$

This problem is different from previous works since τ_t and v_{t-1} are additional state variables for the agent to keep track of, in order to extract useful information about fundamentals from capital controls.

1.2.5 Model Mechanisms

In addition to increasing the cost of borrowing, capital controls affect the representative agent's decision making through two additional mechanisms related to learning from policy. The first mechanism is about precautionary savings. When the agent observes capital controls, she learns more about next period tradable income and is less uncertain about overall income tomorrow. This leads to less saving for precautionary reasons and hence more overall borrowings, which undermines financial stability as borrowings are associated with the pecuniary externality.

To see how this mechanism works in more details, note that the agent accumulates precautionary savings for two reasons:
1. *Prudence.* The third derivative of a CRRA utility function is positive:

$$u(c) = \frac{c^{1-\gamma}}{1-\gamma} \tag{1.33}$$

$$u'''(c) = \gamma(\gamma+1)c^{-\gamma-2} > 0 \tag{1.34}$$

which leads to an increase in savings in response to an increase in future income uncertainty even in the absence of a collateral constraint.
2) *The presence of a collateral constraint.* To illustrate, consider the special case of a quadratic utility function so there is perfect smoothing of tradable consumption in the absence of the collateral constraint. Since nontradable consumption is equal to nontradable endowment each period due to market clearing, we have:

$$c_t^T = E_t c_{t+1}^T \quad \text{if} \quad b_{t+1} > -(\kappa^N p_t^N y_t^N + \kappa^T y_t^T) \tag{1.35}$$

$$c_t^T = b_t(1+R_t) + y_t^T + (\kappa^N p_t^N y_t^N + \kappa^T y_t^T) \quad \text{if} \quad b_{t+1} = -(\kappa^N p_t^N y_t^N + \kappa^T y_t^T) \tag{1.36}$$

The pairwise conditions above can be rewritten in a more concise form:

$$c_t^T = \min[E_t c_{t+1}^T, b_t(1+R_t) + y_t^T + (\kappa^N p_t^N y_t^N + \kappa^T y_t^T)] \tag{1.37}$$

where

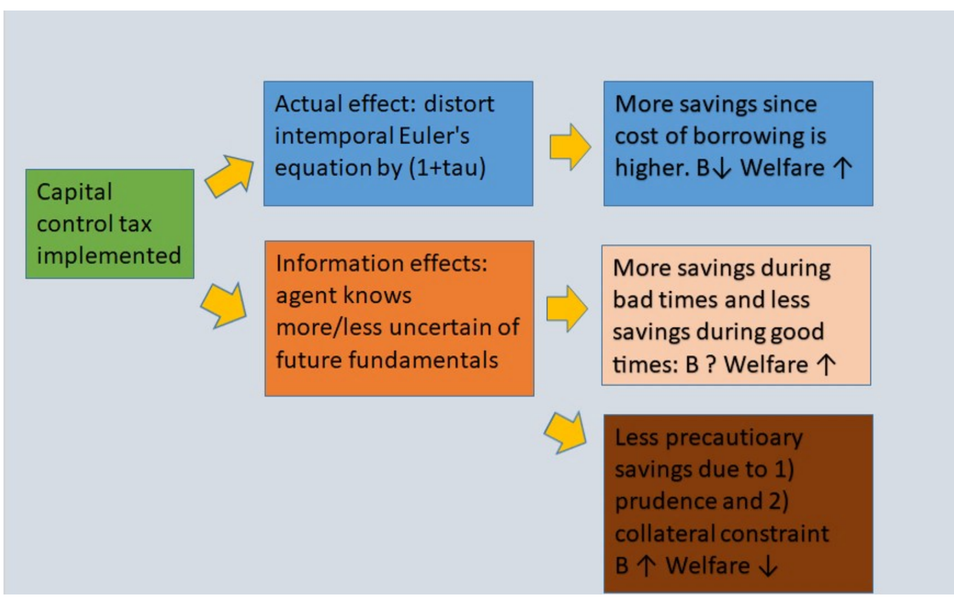
$$E_t c_{t+1}^T = E_t \min[E_{t+1} c_{t+2}^T, b_{t+1}(1+r) + y_{t+1}^T + (\kappa^N p_{t+1}^N y_{t+1}^N + \kappa^T y_{t+1}^T)] \tag{1.38}$$

If future income uncertainty increases, low realization of y_{t+1}^T becomes more likely and the collateral constraint is more likely to bind, reducing the value of the right hand side of equation 1.38 and hence the value of c_t^T. This is a reason to accumulate precautionary savings even in the absence of prudence.

Because of the two reasons above, capital controls can be less efficient in reducing borrowings when the agent learns from it than when she does not. This is because the agent updates her information set and reduces precautionary savings precisely when she sees policy actions. In contrast, the agent in Bianchi, Liu and Mendoza(2016) learns through an exogenous signal and hence the Bayesian updating of the agent's information set is unrelated to policy actions. My model has a distinct feature of a policymaker “fighting against herself”: a tax on bond holdings reduces borrowings and hence mitigates the pecuniary externality associated with it; on the other hand, information revealed through policy action increases borrowing and aggravates the externality.

A second mechanism through which learning affects decision making is one of better timing of borrowing/saving decisions. In the absence of externalities, more information helps the agent make better decisions regarding consumption and hence improves welfare, as the optimal choices in the absence of new information are always available. In this specific setting, news have asymmetric effects due to the collateral constraint (see Guerrieri and Iacoviello(2017) for a discussion of the asymmetry of a collateral constraint when the collateral is housing wealth): goods news have less impact on the agent's decision making since the collateral constraint is more likely to be slack when the collateral is worth more; on the other hand, bad news have more impact because the collateral constraint is more likely to bind when the collateral is worth less. By having more information about the value of future collaterals, the agent borrows less during bad times and more during good times. The effect of this mechanism on overall borrowing is ambiguous, but it increases overall welfare.

Figure 1.4: Model mechanisms



In sum, capital controls influence the agent's decisions through three mechanisms: a conventional mechanism of changing the cost of borrowing and two informational mechanisms involving precautionary savings and better timing of borrowing decisions, respectively. Figure 1.4 summarizes these mechanisms. The implications of learning from policy for policy efficacy depends on the relative strength of each mechanism, which is a quantitative question to be answered in the next section.

1.3 Quantitative Studies

In this section, I calibrate the model to the Brazilian economy and evaluate the quantitative implications of learning about economic fundamentals from capital controls. Using global nonlinear methods as in Bianchi(2011), I solve for the decentralized equilibrium, the equilibrium with policy but no learning and the equilibrium with both policy and learning.

1.3.1 Calibration

Table 1.1 summarizes values assigned to parameters in the model. A period in the model represents a year[6]. The first section follows Bianchi(2011) and Bianchi, Liu and Mendoza(2016) in choosing the relevant moments to target, except that I use Brazilian data instead of Argentinian data to be consistent with the empirical section. The log of tradable income is modeled as a first-order autoregressive process and estimated with the HP-filtered cyclical components of Brazilian tradable GDP from the World Development Indicator(WDI) from 1960 to 2016; the parameter ω is the tradable share in the CES aggregator and is calibrated to match a 33 percent share of tradable production for Brazil; the discount factor β is set so that the average net foreign asset-to-GDP ratio in the model equals its historical average in Brazil, which is equal to -32 percent in Lane and Milesi-Ferretti(2011).

The second section of the table contains parameter values specific to my model with learning from policy. T_m is calibrated to the optimal flat tax rate in Bianchi(2011). In the model, the forecast of next period output and the mean squared forecast error(MSFE) before the agent observes capital controls can be expressed as:

$$E_t y_{t+1}^T(\theta) = \Sigma_l l p(y_{t+1}^T = l | s_t = i, y_t^T = j) \tag{1.39}$$

$$MSFE(\theta) = E_t(E_t y_{t+1}^T(\theta) - y_{t+1}^T)^2 \tag{1.40}$$

After capital controls are observed, the forecast and MSFE of the forecast are updated to

[6] I choose not to calibrate the model to quarterly data because Schmitt-Grohe and Uribe(2018) have shown that a quarterly calibration for this model leads to equilibrium underborrowing instead of overborrowing.

Table 1.1: Calibration of the quantitative model

parameter	value
y^N, nontradable endowment	1
N, number of states for tradable endowments	3
$E[y^T]$, expectation of tradable endowments	1
ρ_{y^T}, persistence of tradable process	0.63
σ_{y^T}, standard deviation of tradable process	0.060
β, discount factor	0.90
γ, coefficient of relative risk aversion	2
$\frac{1}{1+\eta}$, elasticity of substitution	0.83
κ, share of pledgeable collateral	0.34
θ, signal precision	1/3
ω, share of tradable consumption in the aggregator	0.33
R^h, interest rate in low liquidity regime	1.0145
R^l, interest rate in high liquidity regime	0.9672
F_{hh}, persistence of low liquidity regime	0.9333
F_{ll}, persistence of high liquidity regime	0.6
ϕ_0, intercept in the tax rule	14.27
ϕ_1, slope in the tax rule	-10.67
T_m, determinstic component of tax when future income is medium	3.6
ρ_T, persistence of random component of tax	0.9
σ_T, standard deviation of random component of tax	0.8

reflect the arrival of new information:

$$E_t y^T_{t+1}(\theta, \tau_t) = \Sigma_l l p(y^T_{t+1} = l | s_t = i, y^T_t = j, \tau_t = k) \tag{1.41}$$

$$MSFE(\theta, \tau_t) = E_t(E_t y^T_{t+1}(\theta, \tau_t) - y^T_{t+1})^2 \tag{1.42}$$

ρ_T, σ_T and θ are chosen such that $MSFE(\theta, \tau_t) - MSFE(\theta)$, the MSFE reduction resulting from the arrival of new information in capital controls, matches the magnitude measured later in the empirical section, where I complete a nowcast of Brazilian real GDP and use capital control announcements to help improve the nowcast. Given σ_T, ϕ_0 and ϕ_1 are then set such that the agent does not have perfect information regarding next period tradable output after learning from policy.

1.3.2 Quantitative Results

In this section, I compare and contrast the long-run and financial crisis moments of the three different equilibria: the decentralized equilibrium (denoted **D**); the equilibrium with only policy intervention (denoted **P**); the equilibrium with both policy intervention and learning from policy(denoted **PL**). When people learns from capital controls, these policy actions may entail unintended consequences such as higher debt levels and more severe financial crisis in the sense of larger consumption drops and currency depreciation. When the reduction of precautionary savings is strong enough, capital controls may even lead to welfare losses.

Table 1.2: The effects of capital controls and learning from capital controls

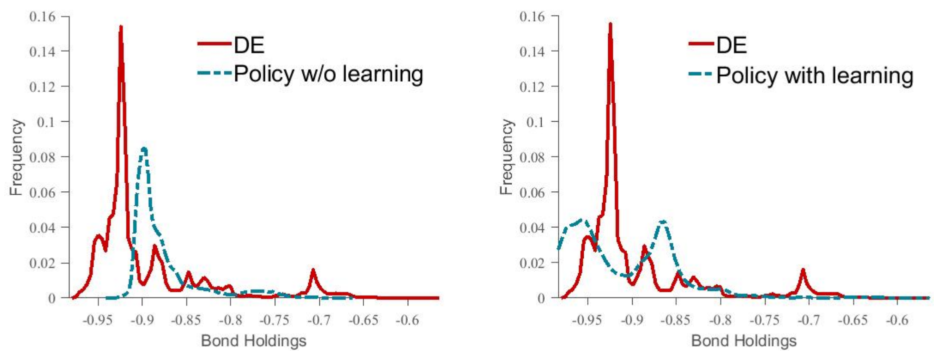
	DE	P	PL
Long-run moments			
Long-run probability of financial crisis	7.53%	1.47%	0.97%
Mean debt/GDP level	30.6	30	31.8
Standard deviation of current account	3.4%	2.0%	2.3%
Welfare gain relative to DE	n.a.	0.14%	0.33%
Financial crisis moments			
Consumption drop in crisis	12.67%	10.05%	13.47%
RER depreciation in crisis	34.66%	26.62%	38.48%
Current account drop in crisis	10.69%	7.93%	12.48%

Financial crisis is defined as a period in simulation when capital outflow exceeds two standard deviation of the mean of the ergodic distribution of current account and the collateral constraint binds.

The first and second columns in Table 1.2 show that the effects of the tax rule are quantitatively similar to these of the Ramsey-optimal tax: financial crisis happens much less frequently, the economy accumulates less debt and the current account is less volatile. Capital controls also reduce the severity of a financial crisis: the magnitudes of consumption drops, real exchange rate depreciations and capital outflows are mitigated by capital controls. The tax rule is associated with a welfare gain of about 0.14% relative to the decentralized equilibrium. These results are consistent with findings in Bianchi (2011) about the effects of an optimal tax. In sum, the assumption of a simple tax rule does not make a material difference in the study of capital controls, allowing me to use the simple rule to facilitate learning from policy.

I proceed to discuss what happens when agent learns from capital controls. The second and third columns in Table 1.2 compares long-run and crisis moments of policy equilibria with and without learning(**PL** and **P**). When the agent learns from policy and saves less for precautionary reasons, the economy accumulates more debt and the current account is more volatile in **PL** than in **P**. A financial crisis is also more severe in **PL**, in the sense of larger consumption drops, real exchange rate depreciations and capital outflows in a crisis. These effects are contrary to the intention of policymakers implementing capital controls. The effect of learning on the frequency of financial crisis is ambiguous: good news, induce more borrowing and a higher likelihood of hitting the collateral constraint, but borrowing capacity also increases since the collateral is worth more. In this calibration, financial crises are slightly less frequent with learning.

Figure 1.5: Ergodic bond holding distributions in **D** and **PL**



However, a more interesting comparison is between the decentralized equilibrium(**D**) and the equilibrium with tax rule and learning(**PL**), namely, between the first and third column of Table 1.2. Most conclusions in the last paragraph are still true: the economy accumulates more debt in **PL** than in **D**; a financial crisis is also more severe. In other words, if agent learns from policy, policymaker could do worse in reducing over-borrowing and mitigating the severity of a financial crisis than if it does nothing to intervene. Figure 1.5 shows the ergodic distribution of bond holdings in **D** and in **PL**. As in Bianchi(2011), in the absence of learning, capital controls reduce the economy's exposures to high debt levels in the left tail of the distribution, as shown in the left panel. With learning, however, this is no longer true: the economy has significant exposures to high debt levels that increases the economy's vulnerability to a financial crisis. The efficacy of capital controls in ensuring financial stability is undermined by the fact that the agent learns about fundamentals of the economy from observed policy measures themselves.

In the baseline results, there is a 0.33% welfare gain of **PL** relative to **D**. In this sense, isn't the policymaker actually doing better when agent learns? It turns out the welfare result in this model with learning from policy is fragile and depend on the relative strength of the three different mechanisms at work. I discuss this in greater details in the next subsection.

1.3.3 Welfare

Are capital controls welfare-improving if agents learn from policy? The answer depends on the relative strength of the different mechanisms at work in the model. Capital controls increases the cost of borrowing, which improves welfare by helping to make financial crises less frequent and less severe. In addition, learning from capital controls has two opposite effects on welfare: more information improves welfare by helping the agent make more informed decisions; more information also reduces precautionary savings and hence reduces welfare when pecuniary externality is present. The net effect of capital controls on welfare depends on whether the perils of less precautionary savings is quantitatively more important than the other two mechanisms combined. The 0.33% welfare gain in table 1.2 is exaggerated because the setting overstates the benefit of more information. I proceed to alter the relative strength of the different mechanisms and show that a smaller welfare gain or even welfare losses are plausible in this model.

I increase the strength of the precautionary savings mechanism and decrease the benefits from more information to show that capital controls can lead to negative welfare gains whe people learns from them. First, I consider the case where a capital control tax is present only some of the time(only when the optimal taxes imposed by a social planner is positive), instead of all the time, as is the case in the benchmark setting. This specification prevents the benefits of having more information from being exaggerated, since the agent is not receiving new information in all states. Let τ_t be the tax rule defined in equations 1.13-1.14 and τ_t^* be the optimal tax defined in equation 1.12, the capital control tax rates are on-and-off now:

$$\tau_t^{New} = 1(\tau_t^* > 0)\tau_t \tag{1.43}$$

Definition 4 defines an equilibrium(denoted **PL2**) with both policy intervention and learning from policy; capital control taxes are on-and-off in this equilibrium.

Definition 4. Given the state contingent processes y_t^T, s_t, R_t, v_t and government policy τ_t^{New}, **PL2** is a sequence of price p_t^N and allocations b_{t+1}, c_t^T, c_t^N such that:
1. Agent maximizes her utility subject to the budget constraint and the collateral constraint, taking p_t^N and τ_t^{New} as given.
2. Government levies capital control tax τ_t^{New} according to equation 1.43.
3. Markets for tradable goods and nontradable goods clear.

4. Agent learns from both the exogenous signal s_t and the capital control tax τ_t^{New} to forecast future tradable income as in equations 1.23-1.26.

Second, I change the relative risk aversion parameter such that the precautionary savings motive is stronger. κ, the share of endowment pledged as collateral, is not suitable for this purpose: if κ is lowered, the agent might have more incentive to insure against hitting the constraint, but financial crisis moments also change at the same time, since a binding constraint is part of the definition of a crisis. Therefore, I increase the strength of the precautionary savings mechanism by experimenting with different values of γ, the coefficient of relative risk aversion.

Table 1.3: Welfare gains under **PL2**

γ	2	2.5	3	4
Welfare gains relative to **D**	-0.13%	-0.16%	-0.2%	-0.34%

Table 1.3 presents welfare gains of capital controls of **PL2** relative to **D** for different values of risk aversion. For empirically plausible values of γ, there is actually welfare losses associated with one-and-off taxes, as the precautionary savings mechanism is stronger than the other two mechanisms combined. This is further confirmed by the fact that the welfare losses are larger as the relative risk aversion parameter takes on higher values.

In sum, if the agent is reasonably risk-averse and capital controls are put on only when necessary, welfare losses due to learning about future fundamentals can be quantitatively more important than welfare gains from policy. Hence, policymakers should consider how others in the economy adjusts their understanding of fundamentals in response to policy actions.

1.3.4 Implications of the model with learning

The implications of this model can help rationalize several findings in the empirical literature of capital controls. First, optimal capital control policy usually constitutes inflow controls in the case of over-borrowing and outflow controls in the case of under-borrowing. Therefore, the presence of learning and information revelation renders inflow controls less efficient than outflow controls in ensuring financial stability, since it reduces precautionary savings in both cases. This is in line with empirical findings in Forbes, Fratzscher and

Straub(2015), where the authors documented that the effects of outflow controls on exchange rate and capital flows are both statistically and economically more significant than these of inflow controls. Second, market participants in countries with on-and-off control measures (Gate countries) may find it easier to learn about fundamentals from repeated experiences than market participants in countries where there is no change to control measures for a long time (Wall countries). Hence, inflow controls should work better in Wall countries than in Gate countries, since learning reduces precautionary savings less in the former. The main empirical findings in Klein (2012) is supportive of this view: among inflow measures, persistent controls are more efficient than episodic measures in reducing financial fragility and moderating exchange rate movements.

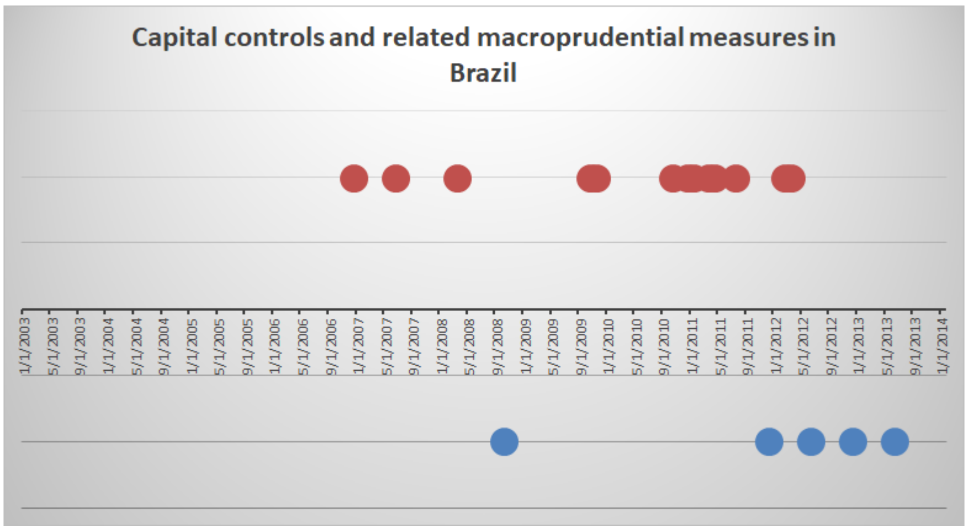
1.4 Measuring the information content of capital controls

My theoretical model assumes that private agent learns about economic fundamentals from capital controls. In the empirical section, I present two complementary sets of empirical evidence on the relationship between capital controls and expectations of fundamentals to justify this assumption. The first set of evidence comes from Brazilian survey data of expectations, a direct measure of market participant's expectations of fundamentals, where the daily frequency of the data allows for relatively clean identification. However, the survey data is an average of expectations of many forecasters using different methodologies, and hence hard to interpret in more details. Therefore, my second set of empirical evidence takes a stand on the methodology used to form expectations. I use a standard econometric model to construct nowcasts for real GDP growth and examines whether capital control announcements help improve nowcast of Brazilian real GDP. Empirical evidence coming from both exercises show that capital controls convey valuable information about economic fundamentals agent uses in their forecasts. The empirical section starts with a brief description of Brazil's experience with capital controls between 2006 and 2013 and proceeds to the two sets of empirical evidence.

1.4.1 Capital controls in Brazil after the Global Financial Crisis

In the empirical section, I focus on Brazil's experience with capital controls after the global financial crisis. Between 2006 and 2013, Brazil adopted a series of well-known capital control measures discussed in many sources (Holland(2013), Chamon and Garcia(2014), Forbes et al.(2016), to name only a few). Most notably, in response to the large capital inflows into emerging markets following the U.S. Federal Reserve's Quantitative Easing programs, the country imposes taxes on short-term portfolio inflow coupled with related macroprudential measures. These efforts are widely considered successful by most policymakers in ensuring financial stability and are promoted by the International Monetary Fund(IMF) as an example to learn from.

Figure 1.6: Capital controls in Brazil: 2006 - 2013



To study the relationship between capital controls and expectations of fundamentals, I construct a daily dummy variable of policy stance containing all capital controls and related macroprudential measures in my sample[7]: 1 represents the introduction or a tightening of a policy measure, -1 removal or loosening and 0 if no action was pursued. Figure 1.6 visualizes the policy stance variable, where a red(blue) dot represents a tightening(loosening) measure. Between 2006 and 2013, there are 18 such policy measures in total, but the majority of these measures are announced between 2010 and 2012. Most of these policy measures were actually implemented at or shortly after the announcement, allowing me to focus on announcement dates alone.

1.4.2 Identification assumption

My empirical findings that capital controls convey negative information about economic fundamentals relies on the identification assumption that a tightening of capital controls

[7]Table A1 and A2 in appendix A contain details of what these measures actually are and their announcement dates, as well as sources.

does not negatively affect real GDP within the current quarter. Hence, my empirical results are not immune to the criticism that forecasters expect capital controls to decrease real GDP and they are simply incorporating this mechanism into their forecasts. I state several reasons to support my assumption. First, there is no academic consensus on how capital controls affect real output. By improving financial stability, a primary function emphasized by the current literature, capital controls can actually be expected to increase output by avoiding the output cost of a financial crisis. Klein(2012) finds not empirical relationship between capital controls and real output. Second, the Brazilian capital controls considered here focuses on short-term portfolio inflows instead of Foreign Direct Investment(FDI) in the hope of retaining productive capital inflows to the economy. This institutional background mitigates concerns that capital controls negatively affect real GDP by decreasing foreign investment which would help improve the economy's productive capacity. Last, capital controls and output are unrelated in the model: tradable and nontradable outputs are endowment driven by an exogenous process, and capital controls improve welfare through better intertemporal consumption smoothing.

1.4.3 Capital controls and high-frequency expectations of fundamentals

My empirical evidence from high-frequency Brazilian survey data suggest that expectations of economic fundamentals respond to capital control announcements. Below, I discuss the nature of the survey data used in this section, conduct event studies on six major capital control announcements in Brazil and measure the revisions of expectations in response to these announcements.

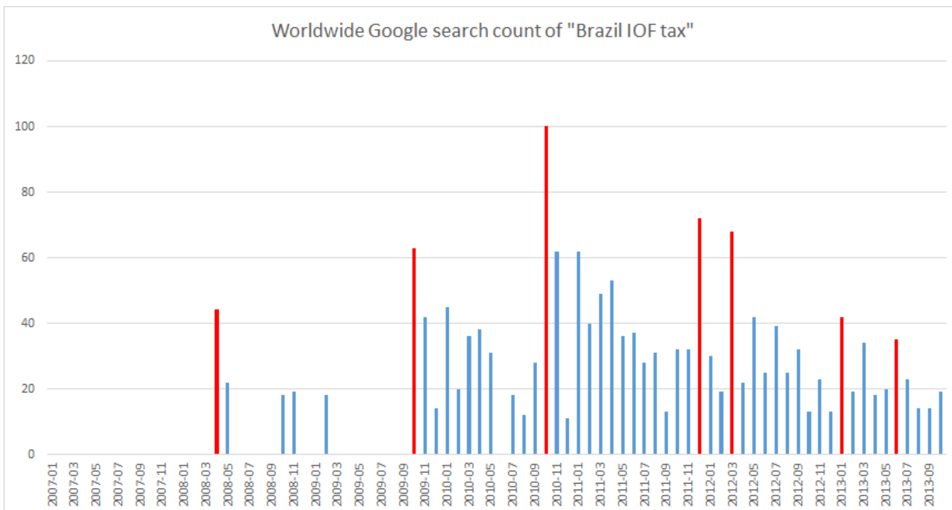
1.4.3.1 Data

Survey data of market expectations used in this section comes from the Brazilian central bank's Market Expectations Systems (MES). Since 1999, the MES collects forecasts of inflation, output growth, industrial production and the policy interest rate at different horizon from around 120 professional forecasters, most of whom are financial institutions or real-sector companies with a forecasting team. The MES only reports summary statistics of the distribution of forecasts. Individual forecasts are not publicly available.

I focus on daily median expectation of Brazilian quarterly real GDP growth for the current quarter, although median expectations for the previous quarter and the next three quarters are also analyzed. Individual forecasters do not submit their forecasts on a daily basis, so daily variation in the expectations data comes from the fact that different forecasters report to the MES system at different points in time. On average, the median daily expectation of quarterly GDP growth changes every 2-3 days.

1.4.3.2 Empirical methodology

Figure 1.7: Google search count of Brazil's IOF tax



I use event study to measure the revisions to median quarterly GDP growth expectation in response to six major capital control news events highlighted in Table A1 and Table A2 in the appendix. Five out of the six events involve the use of tax on portfolio inflows. Announcement of these events are unexpected to market participants. Figure 1.7 shows Google search counts for the phrase *Brazil IOF tax* between 2006 and 2013, and hikes in search counts are highlighted in the figure. A hike usually comes on or after the announcement date of a major capital control event, suggesting the unexpected nature of these announcements. A search of news on or near the six announcement dates yields no information of any other major economic policy announcements on these dix dates, which would confound the event study results. Detailed steps of my event studies are described below:

Step 1. Identify an event window consisting of the day of the announcement of an event(T) and two days prior($t_1 \equiv T-2$) and after($t_2 \equiv T+2$) the announcement.
Step 2. Estimate an AR (1) model($y_t = \alpha + \rho y_{t-1} + \epsilon_t$) for real GDP growth expectations using 30 days of data prior to the event window (these 30 days are called the estimation

window).
Step 3. Use the model to predict GDP growth expectations during the event window($t \in [t_1, t_2]$). These predictions are called counterfactual growth expectations($CE[y_t]$).
Step 4. Calculate abnormal growth expectations during the event window($t \in [t_1, t_2]$) as the difference between actual and counterfactual growth($AE_t = E[y_t] - CE[y_t]$).
Step 5. Calculate mean abnormal growth expectations over the event window($MAE = \frac{1}{t_2 - t_1} \Sigma_{t=t_1}^{t_2} AE_t$).
Step 6. Calculate T-statistic for the hypothesis that mean abnormal growth expectations is zero.

1.4.3.3 Results

Table 1.4 presents the main empirical findings using high-frequency survey data of expectations. Four out of the six major capital control events are associated with statistically significant revisions of growth expectations. The magnitudes of these revisions are economically meaningful and close to the usual adjustments made by a professional forecaster in response to the release of a major news event. On average, an announcement of a tightening(loosening) of capital controls is associated with a downward(upward) revision of growth expectation of around 0.23 percent. This is supportive of the countercyclical capital control policy rule used in my theoretical model. The exception is the tightening announcement in March 2008, when market participants actually revise their growth expectations upward. To sum up, empirical evidence from high-frequency survey data suggests that expectations of fundamentals do respond to capital control measures. However, these results are based on mean expectations of 120 forecasters using different forecasting methodologies, and can be hard to interpret in greater details. Hence, in the next section, I take a stand on the forecasting methodology used to form expectations.

1.4.4 Using capital controls to improve GDP nowcast

In this section, I use a conventional econometric model to nowcast Brazilian quarterly real GDP between 2006 and 2013. The GDP-nowcasts are my preferred measure of the expectation of economic fundamentals and the data series used to produce the nowcasts are my preferred measure of the forecaster's information set. To my knowledge, this methodology is new to the empirical literature of capital controls. I add the dummy variable of policy stance and show that it improves the precision of the GDP-nowcast.

Table 1.4: Event study: capital controls and revisions to GDP growth expectations

Event date	Type	Mean growth forecast revision(%)	T-statistic
3/12/2008	tightening	-0.05**	2.12
10/20/2009	tightening	0.02	-1.40
10/04/2010	tightening	0.70***	-72.79
12/01/2011	loosening	0.02	0.19
03/09/2012	tightening	0.03**	-1.98
06/04/2013	loosening	0.16***	4.77

Coefficient is positive if it has the expected sign. T-statistic reported here are for a statistical test of the hypothesis that mean abnormal growth expectations is zero.

1.4.4.1 Data

I briefly discuss time-series data used to form nowcasts of Brazilian quarterly real GDP growth. All categories of economic data typically included in a GDP-nowcasting model are used here and divided into eight blocks: labor, trade, industrial production, survey, GDP and income, monetary and credit, financial and interest rate, and government finance.[8] All series are monthly data from January 2004 to December 2013. There are capital controls in most of the years in the sample period except 2004 and 2005. These two years are included to have a long enough sample period to train the forecasting model.

1.4.4.2 Empirical methodology

I adopt the econometric framework in Giannone, Reichlin and Small(2008), widely used by central banks in advanced economies, to produce real-time nowcasts of quarterly Brazilian real GDP growth in a ten-year period between 2004 and 2013. Capital control measures are then added to my information set and they are shown to improve the precision of my nowcasts. I briefly describe the econometric framework below and refer interested readers to the original paper for more detail.

Let Ω_{v_j} be the available information set of data vintage v_j following release j in month

[8] Table A3 in the appendix provides details of the data series. Each series is typically released at the same point in time in a given month. Table A3, as a calendar of data release, also gives the order in which data enters into the nowcast model.

v. The information set consists of:

$$\Omega_{v_j} = x_{it|v_j}; t = 1, ..., T_{v_j}, i = 1, ..., n \tag{1.44}$$

where $x_{it|v_j}$ is a generic data series in the information set Ω_{v_j} used to form the nowcast, $i = 1, ..., n$ indexes individual time series (exports, unemployment, etc...), $t = 1, ..., T_{v_j}$ indexes dates a series in vintage v_j is observed (T_{v_j} the period in which series i in vintage v_j is last observed). Assuming no data revisions, the information set is expanding with each release. Let $k = 1, 2, 3, ...$ index quarters, and hence $3k$ represents the third month of a quarter ($3k - 1$ the second month of a quarter and $3k - 2$ the first month). Let y_{3k} be quarterly GDP at the end of the third month of a quarter and M the underlying econometric model. The nowcast of quarterly GDP and the uncertainty of the nowcast conditioning on information set Ω_{v_j} and the underlying model are given by:

$$\hat{y_{3k|v_j}} = E[y_{3k|\Omega_{v_j}}; M] \tag{1.45}$$

$$V(y_{3k|v_j}) = E[(\hat{y_{3k}} - y_{3k})^2; M] \tag{1.46}$$

M is a Dynamic Factor Model(DFM) estimated with a Kalman filter:

$$x_{t|v_j} = \mu + \Lambda F_t + \xi_{t|v_j} \tag{1.47}$$

$$F_t = AF_{t-1} + Bu_t \tag{1.48}$$

where equation 1.47 is the measurement equation and equation 1.48 the transition equation. $x_{t|v_j} = (x_{1t|v_j}, ..., x_{nt|v_j})'$ is a vector of individual monthly data appropriately transformed to induce stationarity, F_t common factors to be extracted, Λ the corresponding factor loadings, $\xi_{t|v_j} = (\xi_{1t|v_j}, ..., \xi_{nt|v_j})'$ a vector of the idiosyncratic component driven by variable-specific shocks and u_t a white noise shock to the common factors. I also assume that $\xi_{t|v_j}$ are cross-sectionally orthogonal white noises, and they are also orthogonal to the common shocks u_t.

After the monthly factors, F_t, are estimated for all months in the quarter, I proceed to obtain monthly GDP nowcasts based on these factors. The following regression is used to obtain coefficients in the nowcasting regression:

$$y_{3k|v_j} = \alpha + \beta F_{3k|v_j} + \epsilon_t \tag{1.49}$$

where $\hat{F}_{3k|v_j}$ is factor estimate at the end of the third month of a quarter. The GDP nowcast at the same point in time is then $\hat{y_{3k|v_j}} = \hat{\alpha} + \hat{\beta}\hat{F}_{3k|v_j}$. GDP-Nowcasts at the end of the 1st and 2nd months can be obtained in a similar way, by projecting quarterly GDP on factor estimates at the end of the corresponding month.

In this framework, the nowcast and the uncertainty of the nowcast change as new data comes into the forecaster's information set. The information content of the news contained in data vintage j+X can be measured as revision of the nowcast $E[y_{3k|\Omega_{v_{j+X}}}; M] - E[y_{3k|\Omega_{v_j}}; M]$ or as the reduction in mean-squared forecast error(MSFE) of the nowcast in response to the release of X:

$$MSFE(\Omega_{v_j}) = E[(\hat{y_{3k}} - y_{3k})^2|\Omega_{v_j}; M] \quad (1.50)$$

$$MSFE(\Omega_{v_{j+X}}) - MSFE(\Omega_{v_j}) = E[(\hat{y_{3k}} - y_{3k})^2|\Omega_{v_{j+X}}; M] - E[(\hat{y_{3k}} - y_{3k})^2|\Omega_{v_j}; M] \quad (1.51)$$

Let Ω_{v_j} be the information set available to the forecaster before capital controls are announced, CC the capital control dummy and Ω_{v_j+CC} the information set after capital controls are announced. The information content of capital controls is given by:

$$MSFE(\Omega_{v_{j+CC}}) - MSFE(\Omega_{v_j}) \quad (1.52)$$

and I estimate the empirical object above by using its sample counterpart.

1.4.4.3 Results

When international capital flows is a major concern for the Brazilian economy, the forecaster obtains a more precise estimate of GDP growth by using capital controls in her information set. Figure 1.8 plots actual Brazilian quarterly GDP growth rates alongside its nowcast at the end of the current quarter. As can be seen, the econometric model does reasonably well in delivering real-time estimates of quarterly GDP. Figure 1.9 proceeds to show the mean forecast error reduction of each data block (at the end of the first month of the quarter)[9]. This exercise allows for the measurement of the information content of capital controls relative to other economic data series. In terms of forecast error reduction, industrial production contains the most important information, followed by income, capital controls and monetary statistics. Financial market variables and government finance data have negligible effects on the nowcast.

[9]Here, I present the forecast error reduction in percentage of GDP growth rate to allow for a more intuitive interpretation. The forecasting literature usually reports these numbers as Mean-Squared Forecast Error(MSFE) normalized by the variance of the series, and I follow this convention in the appendix.

Figure 1.8: Nowcasting Brazilian real GDP growth

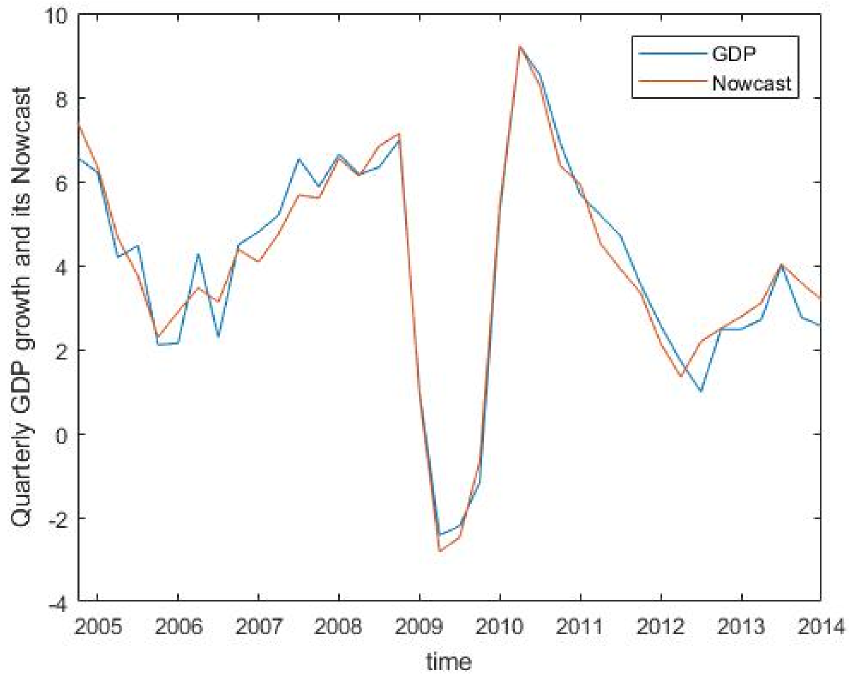


Table 1.5: Capital control announcement and forecast error reduction(FER)

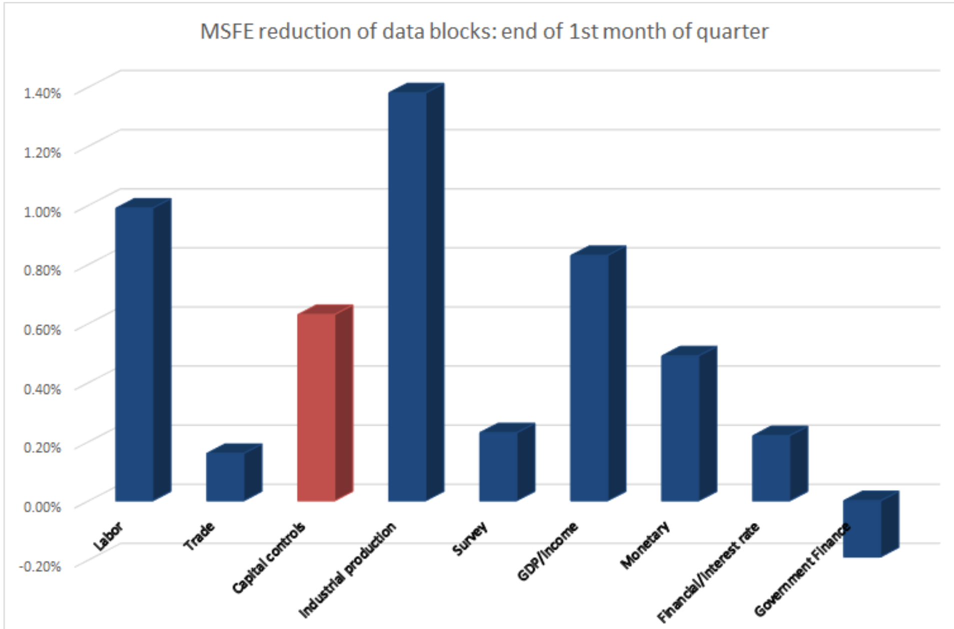
Mean GDP growth	std. GDP growth	FER,1st month	FER,2nd month	FER,3rd month
3.99%	2.67%	0.63%	0.57%	0.69%

My sample period is between 2004Q1 and 2013Q4.

Table 1.5 puts the magnitude of the information conveyed by capital controls in context. During my sample period, Brazilian real GDP growth averages 4% with a standard deviation of 2.7%. After capital control measures are included in the forecaster's information set, the nowcast of current quarter real GDP growth at the end of a given month becomes more accurate by about 0.55%-0.7% in real-time, depending on which month in the quarter is considered.

A caveat of the above result is that unlike other economic data used, capital control announcements can be made at different points in time in a given month instead of at a given time. To use these announcements in the current framework, I need to make a decision where to put them in the calendar of data release. I position capital control announcements such that this decision does not exaggerate the information conveyed by them. For instance, if half of the announcements were made on November 20th in 2009 and the other half made

Figure 1.9: Mean forecast error reduction of different economic data series



on December 10th 2009, capital controls would come into the forecasting model on the 10th of a month and the November 20th announcements would be treated as if they were made on December 10th.

1.4.4.4 Robustness checks

I complete two robustness checks of my nowcasting results: first, my empirical results are robust to the month I consider. When quarterly GDP is projected on factor estimates of the second month or the third month of the current quarter, capital controls is still helpful in obtaining a more precise nowcast[10]. Second, I compare my results for the capital controls dummy against random dummies of similar structure. For this purpose, I generate 500 random dummies of the same length and the same proportion of -1s and 1s in simulation. In each iteration, a random dummy is placed in exactly the same place as the capital control dummy and used alongside the same macroeconomic data to generate a GDP-nowcast. The capital control dummy outperforms 81% of random dummies in terms of MSFE reduction. [11] These exercises show that my finding that capital controls help predict real GDP better

[10]Table A4 in the appendix presents these results in detail.

[11]Figure A1 in the appendix plots the distribution of MSFE reduction of random dummies alongside that of capital controls, shown with the solid red line. It is not surprising that some randomly generated dummies does better than the capital control dummy for this particular sample period. Using one of these in future nowcasting exercises, however, constitutes exactly what one calls data-mining.

is robust to timing and isn't due to spurious correlation.

1.4.4.5 Nowcasting and calibration of theoretical model

The magnitude of the MSFE reduction from capital controls provides a key moment to target in calibration of the theoretical model with learning from policy. In the model, the representative agent completes a Bayesian updating of her information set when she observes capital controls. Certain parameters influence how much the agent learns about fundamentals from policy. I calibrated these parameters such that the MSFE reduction from capital controls in the model matches what I find in the nowcasting exercise in this section.

1.5 Conclusion

This paper contributes to our understanding the role of capital controls in conveying important information about economic fundamentals and the implications of such informational channel for the efficacy of capital controls. I incorporate learning from capital controls in a small open economy model with a collateral constraint and associated pecuniary externality. Capital controls could be less efficient in reducing borrowings and mitigating the severity of a financial crisis when the agent learns from policy and saves less for precautionary reasons. To justify my modeling assumption, I provide empirical evidence that capital controls contain useful information about economic fundamentals people use in their forecasts. My findings point to the idea that in designing macroprudential policy, the policymaker has to consider that the environment in which she operates is not invariant to policy itself: it changes as information about the environment is being transmitted through policy actions.

The finding that learning from capital controls undermines its efficacy is a result of the current modeling environment of over-borrowing relative to the socially-optimal level. In such a setting, learning and information revelation reduces precautionary savings precisely when such savings mitigates the pecuniary externality. Schmitt-Grohe and Uribe(2018) have pointed out that under certain conditions, fear of self-fulfilling crisis may lead to under-borrowing in this class of model. In such an alternative setting, learning and information revelation reduces precautionary savings when the agent saves too much. Therefore, learning from policy is instead expected to enhance policy efficacy by reducing the size of the capital control tax necessary to rule out self-fulfilling crisis and multiple-equilibria. This extension is planned for future research.

CHAPTER II

Capital Controls and Signaling: the Case of Self-fulfilling Crisis and Multiple Equilibria

2.1 Introduction

Since the global financial crisis, capital controls are becoming more accepted as a standard policy tool for emerging market economies to deal with destabilizing financial flows. The academic literature is now focused on better understanding the proper role of capital controls. However, there is limited attention on policymaker's signaling of information about economic fundamentals and market participant's learning of fundamentals from policy actions. Also, the literature and the first chapter of this dissertation focuses almost exclusively on versions of a small open economy model in which the representative agent over-borrows relative to the social optimum, there is a unique equilibrium and capital controls are preventive measures targeting capital inflows. In this chapter, I consider the role of signaling of information about fundamentals in Schmidt-Grohe and Uribe(2018)'s setting, where the agent underborrows relative to the social optimum to insure herself from self-fulfilling financial crisis and capital controls are used to discourage capital outflows at the time of crisis.

I start by describing a model with equilibrium underborrowing and signaling of fundamentals from policy. As in Schmidt-Grohe and Uribe(2018), there are multiple equilibria in which the agent borrows less than they would if they could internalize the effects of their action on the value of collaterals. In addition, as in the first chapter, the government knows more about future economic fundamentals than the agent; the agent knows the government is levying capital control taxes according to a simple policy rule which reveals useful information previously unknown to her. In this setting, signaling of fundamentals enhances policy efficacy because it reduces precautionary savings precisely when such savings are excessive relative to the social optimum. In a simple analytical example with sunspots, I show that the capital control tax rate required to restrict the agent's expected probability of a financial crisis to a given range is smaller with signaling than without. I proceed to calibrate the model and show that the median tax rate required to eliminate underborrowing is 2.7% without signaling, compared to only 2.0% with signaling.

Empirically, I provide some evidence to support the assumption that expectations of economic fundamentals respond to capital controls. The experience of Iceland between 2008 and 2017 is especially relevant for this purpose: after a large banking crisis, the country suffered from massive capital outflows and nonfundamental runs on its currency due to pessimistic views; policymakers decided to impose strict controls on capital outflows to stabilize the value of its currency, the solvency of its banking system and to restore confidence in the Icelandic economy. Using various narrative sources, I construct a list of all capital controls and related macroprudential policy announcements in Iceland between 2008 and 2017. I employee a commonly-used econometric model and use all available time-series data to produce a nowcast of Icelandic quarterly GDP growth in real-time. Including capital control announcements in the forecaster's information set helps improve the precision of her GDP growth nowcast, my preferred measure of expectations of fundamentals.

This chapter contributes to the recent theoretical literature of macro-prudential policy and capital controls. It builds on the theoretical and quantitative framework in Schmitt-Grohe and Uribe(2018), in which the authors studied an environment where the representative agent underborrows relative to the social optimum for fear of self-fulfilling financial crisis driven by nonfundamental runs. This setting stands in contrast to the over-borrowing result stressed in the literature, and the role of capital controls is also different: by threatening to tax capital outflows, capital controls eliminate possibilities of self-fulfilling crisis and remove the need for the agent to engage in excessive precautionary savings, thereby encouraging more borrowings. In the first chapter, I consider the role of information revelation in the usual setting of over-borrowing: learning from policy increases borrowing, aggravates a financial crisis but has ambiguous effects on welfare. Hence, it is not clear whether the government should use signaling in conjunction with policy action itself. In contrast, this paper has clearer policy implications for signaling since it unambiguously enhances policy efficacy.

2.2 A Model of Self-fulfilling Crisis, Capital Controls and Signaling of Fundamentals

In this section, I describe an open-economy model with a flow collateral constraint and with policymaker's signaling of fundamentals. The model follows Schmitt-Grohe and Uribe (2018), in which the private agent underborrows relative to the social planner because she engages in excessive precautionary savings to self-insure against self-fulfilling financial crisis. Capital controls are used to deter capital outflows in times of crisis in order to rule out socially inefficient equilibria of underborrowing. My setting differs from existing literature in the following sense: policymaker possesses superior information about economic fundamentals and actively signals this information through a stochastic policy rule; the agent learns from observed policy actions and improves her understanding of fundamentals.

2.2.1 Representative Agent's Problem

The representative agent has the following preference:

$$E_0 \Sigma_{t=0}^{\infty} \beta^t u(c_t) \tag{2.1}$$

$$c_t = A(c_t^T, c_t^N) = [a(c_t^T)^{1-\frac{1}{\xi}} + (1-a)(c_t^N)^{1-\frac{1}{\xi}}]^{\frac{1}{1-\frac{1}{\xi}}} \tag{2.2}$$

where the period utility function $u(.)$ has the CRRA form and c_t is a CES aggregator of tradable and nontradable goods with elasticity of substitution ξ. In each period, the agent receives an endowment of tradable goods y_t^T, which follows a first-order Markov process, and an endowment of nontradable goods y_t^N, normalized to 1 for convenience.

The agent has access to a one-period, non state-contingent, internationally-traded bond denominated in units of tradables. d_{t+1} is the amount of debt assumed in period t and maturing in t+1. The bond pays an interest rate r_t, which follows an exogenous process driven by global liquidity conditions. In each period, the government levies capital control tax τ_t on debt acquired in period t. Tax revenue is rebated to the agent as a lump-sum transfer, l_t.

In each period, the agent maximizes the expected discounted sum of her utility subject to equation 2.3, her budget constraint and equation 2.4, her collateral constraint:

$$c_t^T + p_t^N c_t^N + d_t = (1-\tau_t)\frac{d_{t+1}}{1+r_t} + y_t^T + p_t^N y_t^N + l_t \tag{2.3}$$

$$d_{t+1} \leq \kappa(y_t^T + p_t^N y_t^N) \tag{2.4}$$

where κ is the share of endowment income pledgeable as collateral and the price of tradables is normalized to 1. The first order conditions with respect to c_t^T,c_t^N and d_{t+1} are given below:

$$\lambda_t = u'(A(c_t^T, c_t^N))A'(c_t^T, c_t^N) \equiv \Lambda(c_t^T) \tag{2.5}$$

$$p_t^N = (\frac{1-a}{a})(\frac{c_t^T}{c_t^N})^{\frac{1}{\xi}} \tag{2.6}$$

$$\frac{\lambda_t}{1+r_t} = (1+\tau_t)E_t\lambda_{t+1} + \mu_t \tag{2.7}$$

where λ_t and μ_t are Lagrangian multipliers of the budget constraint and the collateral constraint. They may be interpreted as the shadow value of wealth and the shadow value of relaxing the collateral constraint. $u'(A(c_t^T, c_t^N))A'(c_t^T, c_t^N)$ is the marginal utility of tradable consumption. The first-order conditions have the same interpretations as in the first chapter. We also have the following complementary slackness conditions:

$$d_{t+1} \leq \kappa(y_t^T + p_t^N y_t^N) \tag{2.8}$$

$$\mu_t \geq 0 \tag{2.9}$$

$$(d_{t+1} - \kappa(y_t^T + p_t^N y_t^N))\mu_t = 0 \tag{2.10}$$

Finally, markets for both tradable and nontradable goods clear:

$$c_t^N = y_t^N \tag{2.11}$$

$$d_t + c_t^T = \frac{d_{t+1}}{(1+r_t)} + y_t^T \tag{2.12}$$

2.2.2 Government and Capital Controls

The government knows tradable income one period ahead. To correct the pecuniary externality associated with the collateral constraint, it implements capital control policy by taxing next period debt holdings of the agent. The tax distorts the agent's intertemporal Euler's equation by making the effective interest rate on future debt higher. Capital control tax rate is determined by the following policy rule, as in the first chapter:

$$\tau_t = \phi_0 + \phi_1 y_{t+1} + v_t \tag{2.13}$$

$$v_t = \alpha + \rho v_{t-1} + \epsilon_t \tag{2.14}$$

The policy rule consists of two components: the first component is related to next-period tradable income. $\phi_1 < 0$ captures the procyclical nature of optimal capital control tax as shown in Schmitt-Grohe and Uribe(2016). The second component of the policy rule is a random shock term which follows an AR(1) process. Its interpretation is analogous to the random shock term in a Taylor rule for monetary policy. I assume that the shock term is uncorrelated with other state variables.

The government knows both components and hence the tax rate τ_t, while the agent only observes τ_t, but cannot tell its components apart. The government signals its superior information about fundamentals by making it clear that the tax rate is determined by the rule specified in equations 2.13-2.14. As in Schmidt-Grohe and Uribe(2018), the Ramsey optimal tax rate for a social planner is given by:

$$\tau_t^* = 1 - \beta(1 + r_t) E_t \frac{u'(A(c_{t+1}^T, y_t^N)) A'(c_{t+1}^T, y_t^N)}{u'(A(c_t^T, y_t^N)) A'(c_t^T, y_t^N)} \tag{2.15}$$

I will refer to the equilibrium when the government imposes the tax above as the social planner's equilibrium in the quantitative section.

I consider a policy rule for the tax rate instead of the Ramsey-optimal tax for three reasons: first, the optimal tax schedule varies across different states in a complicated way, so regulators may find it difficult to implement it in time to respond to an ongoing financial crisis. Second, this tax rule is quantitatively similar to an optimal tax in ruling out equilibria with underborrowing. Last but not least, this simple rule facilitates learning by the agent about economic fundamentals: an optimal state-contingent tax may be too hard to learn from.

Finally, all tax revenue collected are rebated to the representative agent as a lump-sum transfer and the government budget balances in each period:

$$l_t = \tau_t \frac{d_{t+1}}{1 + r_t} \tag{2.16}$$

2.2.3 Signaling and Information Structure

In this section, I describe how the agent's information set changes when she learns from policy. Since the government communicates the nature of the policy rule, the agent can complete a Bayesian updating of her information set when she observes τ_t.

Hence, her estimates of the likelihood of observing a certain tax rate conditioning on next period tradable income is:

$$p(\tau_t = k|y^T_{t+1} = l) = p(\phi y^T_{t+1} + v_t = k|y^T_{t+1} = l) = p(v_t = k - \phi l) \tag{2.17}$$

In this equation, the agent knows the underlying process for v_t, but she does not observe v_t directly. To extract useful information from capital controls, she must form an estimate of $p(\tau_t = k|y^T_{t+1} = l)$. The agent knows the random component of the tax rule last period, since $v_{t-1} = \tau_{t-1} - \phi y_t$ and both τ_{t-1} and y_t are observed at this point. So her estimates involves keeping track of last period realization of the random component and using it to form expectations:

$$p(v_t = k - \phi l) = p(\alpha + \rho v_{t-1} + \epsilon_t = k - \phi l) = p(\epsilon_t = k - \phi l - \alpha - \rho v_{t-1}) \tag{2.18}$$

The agent's learning process is given by the Bayes rule and the law of total probability:

$$p(y^T_{t+1} = l|\tau_t = k) = \frac{p(\tau_t = k|y^T_{t+1} = l)p(y^T_{t+1} = l)}{\Sigma_n p(\tau_t = k|y^T_{t+1} = n)p(y^T_{t+1} = n)} \tag{2.19}$$

Conditioning on y^T_t, we have:

$$p(y^T_{t+1} = l|y^T_t = j, \tau_t = k) = \frac{p(\tau_t = k|y^T_{t+1} = l)p(y^T_{t+1} = l|y^T_t = j)}{\Sigma_n p(\tau_t = k|y^T_{t+1} = n)p(y^T_{t+1} = n|y^T_t = j)} \tag{2.20}$$

where τ_t is the tax observed in period t. If the agent observes a capital control tax, the precision of her forecast regarding future tradable income increases. Finally, the joint evolution of income and capital control tax is given by:

$$p(y^T_{t+1} = l, \tau_{t+1} = n|y^T_t = j, \tau_t = k) = \tag{2.21}$$

$$p(\tau_{t+1} = n|y^T_{t+1} = l)p(y^T_{t+1} = l|y^T_t = j, \tau_t = k) \tag{2.22}$$

where

$$p(\tau_{t+1} = n|y^T_{t+1} = l) = \Sigma_k p(\tau_{t+1} = n|\tau_t = k)p(\tau_t = k|y^T_{t+1} = l) \tag{2.23}$$

This joint process is then combined with the evolution of other exogenous state variables to form the entire transition probability matrix the agent uses to form expectations in her dynamic programming problem.

2.2.4 Equilibrium definition

I define four equilibrium concepts here: the decentralized equilibrium(denoted **D**), where there is no policy intervention at all; The Ramsey equilibrium(denoted **R**), where government implements the Ramsey-optimal tax to fully internalize the pecuniary externalities; the equilibrium with policy intervention through the capital control policy rule but no learning from policy(denoted **P**); the equilibrium with both the policy rule and learning from policy (denoted **PL**).

Definition 1 defines a decentralized equilibrium in the domestic economy.

Definition 1. Given the state contingent processes y_t^T, R_t and given that $\tau_t = 0 \forall t$, **D** is a sequence of price p_t^N and allocations d_{t+1}, c_t^T, c_t^N such that:
1. Agent maximizes her utility subject to the budget constraint and the collateral constraint, taking p_t^N as given.
2. Markets for tradable goods and nontradable goods clear.

Definition 2 defines the Ramsey-optimal equilibrium.

Definition 2. Given the state contingent processes y_t^T, R_t and government policy τ_t^*, **R** is a sequence of price p_t^N and allocations d_{t+1}, c_t^T, c_t^N such that:
1. Agent maximizes her utility subject to the budget constraint and the collateral constraint, taking p_t^N and τ_t^* as given.
2. Government levies capital control tax τ_t^* according to equation 2.15.
3. Markets for tradable goods and nontradable goods clear.

Definition 3 defines an equilibrium with policy intervention through the capital control policy rule but no learning from policy(denoted **P**).

Definition 3. Given the state contingent processes y_t^T, R_t, v_t and government policy τ_t, **P** is a sequence of price p_t^N and allocations d_{t+1}, c_t^T, c_t^N such that:
1. Agent maximizes her utility subject to the budget constraint and the collateral constraint, taking p_t^N and τ_t as given.
2. Government levies capital control tax τ_t according to equations 2.13-2.14.
3. Markets for tradable goods and nontradable goods clear.

Definition 4 defines an equilibrium with both the policy rule and learning from policy.

Definition 3. Given the state contingent processes y_t^T, R_t, v_t and government policy τ_t, **PL** is a sequence of price p_t^N and allocations d_{t+1}, c_t^T, c_t^N such that:
1. Agent maximizes her utility subject to the budget constraint and the collateral constraint,

taking p_t^N and τ_t as given.

2. Government levies capital control tax τ_t according to equations 2.13-2.14.

3. Markets for tradable goods and nontradable goods clear.

4. Agent learns from the capital control tax τ_t to forecast future tradable income as in equations 2.17-2.20.

In the last equilibrium, the dynamic programming problem of the agent in recursive form is as follows, where exogenous state variables are collected in the vector $z_t = (y_t^T, R_t, \tau_t, v_{t-1})'$:

$$V_t(d_t, z_t) = \underset{c_t^T, c_t^N, d_{t+1}}{max} [u([a(c_t^T)^{-\eta} + (1-a)(c_t^N)^{-\eta}]^{-\frac{1}{\eta}}) + \beta E_{z_{t+1}|z_t} V_{t+1}(d_{t+1}, z_{t+1})] \tag{2.24}$$

subject to

$$c_t^T + p_t^N c_t^N + d_t = (1-\tau_t)\frac{d_{t+1}}{1+r_t} + y_t^T + p_t^N y_t^N + l_t \tag{2.25}$$

$$d_{t+1} \leq \kappa(y_t^T + p_t^N y_t^N) \tag{2.26}$$

This problem is different from previous works since τ_t and v_{t-1} are additional state variables for the agent to keep track of, in order to extract useful information about fundamentals from capital controls.

2.2.5 Underborrowing

Before discussing the role of signaling through capital controls, I briefly review related findings in Schmidt-Grohe and Uribe (2018): first, there exists multiple equilibria which satisfy definition 1. Second, among these equilibria which satisfy definition 1, one or more could involve underborrowing in the sense that external debt level in equilibrium is lower than the debt level in the Ramsey-optimal equilibrium. Finally, an optimal capital control tax defined by equation 2.15 eliminates equilibria associated with underborrowing by ruling out the possibility of self-fulfilling runs.

This paper builds on the above results and explores the role of capital controls in signaling about economic fundamentals. Two additional findings are presented in this section: first, the capital control tax rule introduced in this paper can help mitigate underborrowing and gets the decentralized equilibria as close to the Ramsey-optimal equilibrium as possible. Second, and most importantly, if the agent learns about economic fundamentals from the capital control tax rule, the tax rate required to mitigate underborrowing will be smaller than without learning.

2.2.6 An Illustrative Example with Sunspots

In this section, I provide a simple analytical example in which the capital control tax rate required to rule out unintended equilibria is smaller with signaling than without. This example follows Schmidt-Grohe and Uribe(2018) in using a sunspot to help coordinate expectations and generate multi-period financial crisis.

The economy is in the same environment as previously described, with one modification: an exogenous random variable, s_t, also known as a sunspot, takes one the values 0 or 1. If s_t is 1, the agent feels pessimistic; if s_t is 0, however, the agent feels optimistic. The sole role of the variable is to coordinate expectations.

The economy starts with pessimistic sentiments, so $s_0 = 1$. In period 1, s_t is 1 with probability π and 0 with probability $1 - \pi$. Suppose pessimism lasts for at most 2 periods, so $s_t = 0$ for all $t \geq 2$. There exists a value of π which supports a two-period self-fulfilling financial crisis(collateral constraint binds in periods 0 or 1) as a rational equilibrium. Let $c^T_{1,i}$ be the levels of tradable consumption in period 1 if $s_1 = i$. As shown in Schmidt-Grohe and Uribe (2018), $c^T_{1,0} \geq c^T_0$ and $c^T_{1,1} \leq c^T_0$: if the collateral constraint does not bind in period 1 and the economy reaches a steady-state, the agent consumes more in period 1 than in period 0; if the collateral constraint binds in period 1 and the economy experiences a self-fulfilling crisis, the agent consumes less in period 1 than in period 0.

Without a capital control tax, the Euler equation can be rewritten as:

$$\Lambda(c^T_t)[1 - (1 + r)\mu_t] = E_t \Lambda(c^T_{t+1}) \tag{2.27}$$

one can pick values of π to ensure that the Euler's equation holds in period 0:

$$\Lambda(c^T_0)[1 - (1 + r)\mu_0] = \pi \Lambda(c^T_{1,1}) + (1 - \pi)\Lambda(c^T_{1,0}) \tag{2.28}$$

Since $c^T_{1,1} \leq c^T_0 \leq c^T_{1,0}$ and $\Lambda(.)$ is a decreasing function, there exists a range of π which ensures $\mu_0 \geq 0$, and hence guarantees existence of equilibrium. The range is given by $\pi \in (0, \pi^*]$ where

$$\pi^* \equiv \frac{\Lambda(c^T_0) - \Lambda(c^T_{1,0})}{\Lambda(c^T_{1,1}) - \Lambda(c^T_{1,0})} \tag{2.29}$$

In order for a two-period financial crisis to be possible, the agent has to assign a sufficiently high probability(1-π^*) to the event that the economy will emerge from the crisis at $t = 1$.

When the government imposes a capital control tax τ, the expression of π^*, the upper bound of the range of expected probability of a crisis, becomes:

$$\pi^* \equiv \frac{(1-\tau)\Lambda(c_0^T) - \Lambda(c_{1,0}^T)}{\Lambda(c_{1,1}^T) - \Lambda(c_{1,0}^T)} \tag{2.30}$$

As can be seen, the range shrinks as the tax rate increases. Specifically, the optimal tax required to fully eliminate expectations of a financial crisis is given by the tax rate such that $\pi^* = 0$:

$$\tau^o = 1 - \frac{\Lambda(c_{1,0}^T)}{\Lambda(c_0^T)} \tag{2.31}$$

When capital control taxes reveal information about next period tradable income realization, agent saves less for precautionary reasons because they fear less about a self-fulfilling crisis. The agent's assessment of the likelihood of a crisis, π, are also adjusted to reflect the fact that signaling makes a crisis less likely. I assume that the agent assigns a smaller likelihood of crisis with signaling:

$$\pi_s = \pi - \alpha\tau \tag{2.32}$$

Let τ_s and τ be the tax rates necessary to restrict the range of crisis probability to $\pi \in (0, \pi^*]$ with and without signaling, respectively. These tax rates are defined by:

$$\pi^* + \alpha\tau_s = \frac{(1-\tau_s)\Lambda(c_0^T) - \Lambda(c_{1,0}^T)}{\Lambda(c_{1,1}^T) - \Lambda(c_{1,0}^T)} \tag{2.33}$$

$$\pi^* = \frac{(1-\tau)\Lambda(c_0^T) - \Lambda(c_{1,0}^T)}{\Lambda(c_{1,1}^T) - \Lambda(c_{1,0}^T)} \tag{2.34}$$

And hence

$$\frac{(1-\tau)\Lambda(c_0^T) - \Lambda(c_{1,0}^T)}{(1-\tau_s)\Lambda(c_0^T) - \Lambda(c_{1,0}^T)} = \frac{\pi^*}{\pi^* + \alpha\tau_s} \leq 1 \tag{2.35}$$

so $\tau_s \leq \tau$: the tax rate required to restrict the agent's subjective probability of a crisis to a given range is smaller with signaling than without.

Specifically, the optimal tax with signaling, $\tau_{s,o}$, is given by:

$$\alpha\tau_s = \frac{(1-\tau_{s,o})\Lambda(c_0^T) - \Lambda(c_{1,0}^T)}{\Lambda(c_{1,1}^T) - \Lambda(c_{1,0}^T)} \tag{2.36}$$

since $(1-\tau_{s,o})\Lambda(c_0^T) - \Lambda(c_{1,0}^T) \geq 0$ from the above equation, we have:

$$\tau_{s,o} \leq 1 - \frac{\Lambda(c_{1,0}^T)}{\Lambda(c_0^T)} = \tau^o \tag{2.37}$$

The optimal tax rate, the rate required to fully eliminate expectations of a self-fulfilling financial crisis, is smaller with signaling than without. Signaling allows the policymaker to achieve the same policy objective with a smaller tax rate. In the next section, I calibrate the full dynamic model described earlier and confirm this result in quantitative studies.

2.3 Quantitative Results

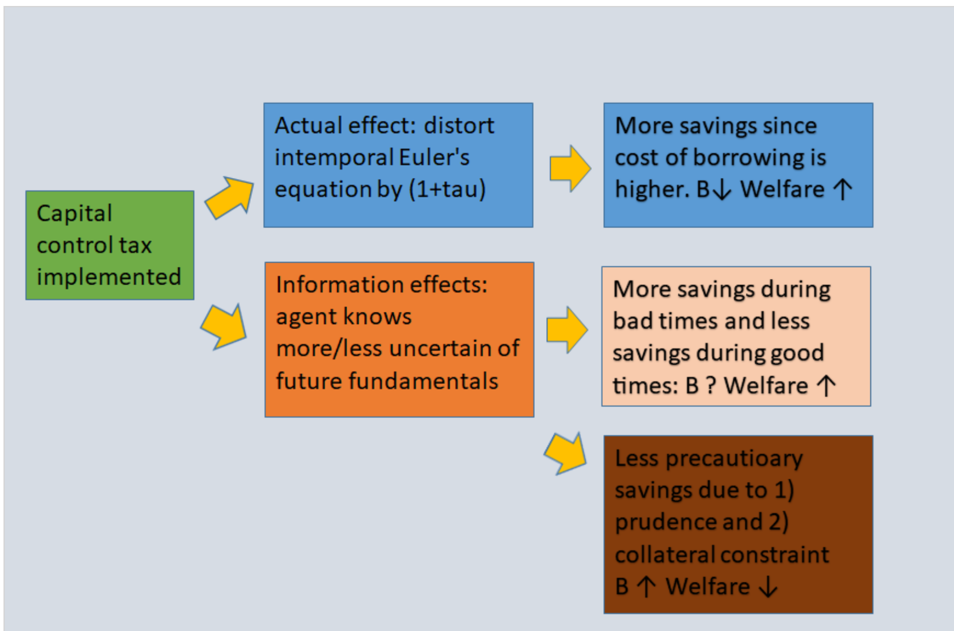
2.3.1 Mechanisms

In the current setting where agent learns from policy, capital controls influence borrowing decisions through three separate mechanisms. First, as in Schmidt-Grohe and Uribe(2018), capital controls can help increase borrowing to the desired level: a threat to tax capital outflows in the event of a self-fulfilling crisis eliminates the crisis as a possible outcomes, and the agent no longer engages in excessive precautionary savings as a way to self-insure. Two additional mechanisms arise because the agent learns about fundamentals from policy: first, the agent is more certain about future income and saves less for precautionary reasons; second, the agent has more information about when the collateral constraint will bind. I discuss the two information mechanisms below.

When capital controls reveal information about future tradable income, the agent is less uncertain about overall income tomorrow and saves less for precautionary reasons. In this model, the agent engages in precautionary savings for two reasons: *prudence* due to the positive third derivative of the CRRA utility function and *the presence of a collateral constraint*. Both reasons lead to a rise(fall) in savings in response to an increase(decrease) in future income uncertainty. Therefore, capital controls can be more efficient when they signal information about future fundamentals, since signaling increases borrowing precisely when more borrowing is desirable. This mechanism works alongside the main mechanism in Schmidt-Grohe and Uribe(2018) to eliminate equilibrium with underborrowing.

Because more information is signaled through policy, the agent knows more about when the collateral constraint will bind and hence times her borrowing/saving decisions better. In this setting, news have asymmetric effects due to the collateral constraint: goods news have less impact on the agent's decision making since the collateral constraint is more likely to be slack when the collateral is worth more; on the other hand, bad news have more impact because the collateral constraint is more likely to bind when the collateral is worth less. By having more information about the value of future collaterals, the agent borrows less during bad times and more during good times. This mechanism has ambiguous effect of borrowing, but should be welfare-improving. The three mechanisms are summarized in figure 2.1.

Figure 2.1: Model mechanisms



2.3.2 Calibration

Table 2.1 summarizes parameter values used to calibrate the quantitative model. The first section follows Schmidt-Grohe and Uribe(2018) in choosing relevant moments to target. They calibrate this model at quarterly frequency to obtain equilibrium underborrowing. This is because κ is larger than 1 at quarterly frequency and hence an increase in debt increases collateral value by more than one for one. In contrast, Bianchi(2011) and Bianchi, Liu and Mendoza(2016) calibrate this model at annual frequency and κ is between 0.3 and 0.4, ruling out equilibrium underborrowing. There are a few departures from Schmidt-Grohe and Uribe(2018): I discretize the state space using 3 grid points for tradable income instead of 21 grid points, because having fewer states for economic fundamentals facilitates learning from policy. Accordingly, β, the discount factor, is chosen differently so the model still target the same aggregate debt level as in their paper.

Table 2.1: Calibration of the quantitative model

parameter	value
y^N, nontradable endowment	1
N, number of states for tradable endowments	3
$E[y^T]$, expectation of tradable endowments	1
ρ_{y^T}, persistence of tradable process	0.79
σ_{y^T}, standard deviation of tradable process	0.035
β, discount factor	0.972
γ, coefficient of relative risk aversion	2
ξ, elasticity of substitution between tradable and nontradable goods	0.5
κ, share of pledgeable collateral	1.2
a, share of tradable consumption in the aggregator	0.26
r, steady state quarterly country interest rate	0.0316
T_m, median of determinstic component of tax	2.7
ρ_T, persistence of random component of tax	0.9
σ_T, standard deviation of random component of tax	0.8

The second section of the table contains parameter values specific to my model. In the model, the forecast of next period output and the mean squared forecast error before the agent observes capital controls can be expressed as:

$$E_t y^T_{t+1} = \Sigma_l l p(y^T_{t+1} = l | y^T_t = j) \tag{2.38}$$

$$MSFE_0 = E_t(E_t y^T_{t+1} - y^T_{t+1})^2 \tag{2.39}$$

After capital controls are implemented, the forecast and associated uncertainty of the forecast are updated to reflect the arrival of new information:

$$E_t y^T_{t+1}(\tau_t) = \Sigma_l l p(y^T_{t+1} = l | y^T_t = j, \tau_t = k) \tag{2.40}$$

$$MSFE(\tau_t) = E_t(E_t y^T_{t+1}(\tau_t) - y^T_{t+1})^2 \tag{2.41}$$

ρ_T and σ_T are chosen such that $MSFE(\tau_t) - MSFE_0$, the MSFE reduction resulting from capital controls, matches what I find in the empirical section, where the usefulness of capital control announcements is assessed through the lens of an econometric model to nowcast Iceland's GDP between 2008 and 2017. Given σ_T, ϕ_0 and ϕ_1 are then set such that the agent does not have perfect information regarding next period tradable output after learning.

2.3.3 Quantitative Results

In this section, I present the main quantitative results: when capital controls signal information about economic fundamentals, government can eliminate equilibrium underborrowing with a tax rate lower than the required tax rate without signaling. Figure 2.2 plots the density of the external debt in the Ramsey equilibrium alongside the densities in the decentralized equilibria. As can be seen, there are multiple decentralized equilibria(equilibria satisfying definition 1) with underborrowing relative to the social-optimum.

Figure 2.2: Equilibrium underborrowing

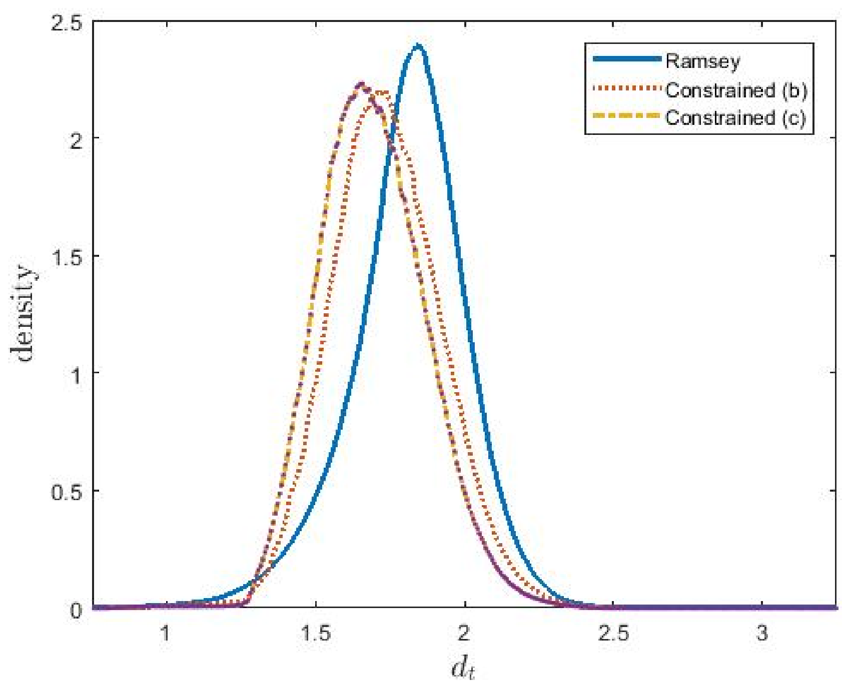


Figure 2.3 plots the density of the external debt in the Ramsey equilibrium alongside debt densities for equilibria with tax rule (definition 3 and definition 4). There is little or no underborrowing and no multiplicity of equilibrium in the economy with the tax rule. Table 2.2 presents the median debt level for different equilibria: elimination of pessimistic equilibria in figure 3 can be achieved with the tax rule both with and without signaling. However, the median tax rate is 2.7% in the case without signaling, as compared to only 2.0% in the case with signaling. These results highlight the importance and usefulness of signaling about economic fundamentals for policy efficacy in this setting. Policymakers should consider communicating such information when they deploy capital controls in the face of massive capital outflows driven by nonfundamental runs.

Figure 2.3: Equilibrium underborrowing: tax rule and signaling

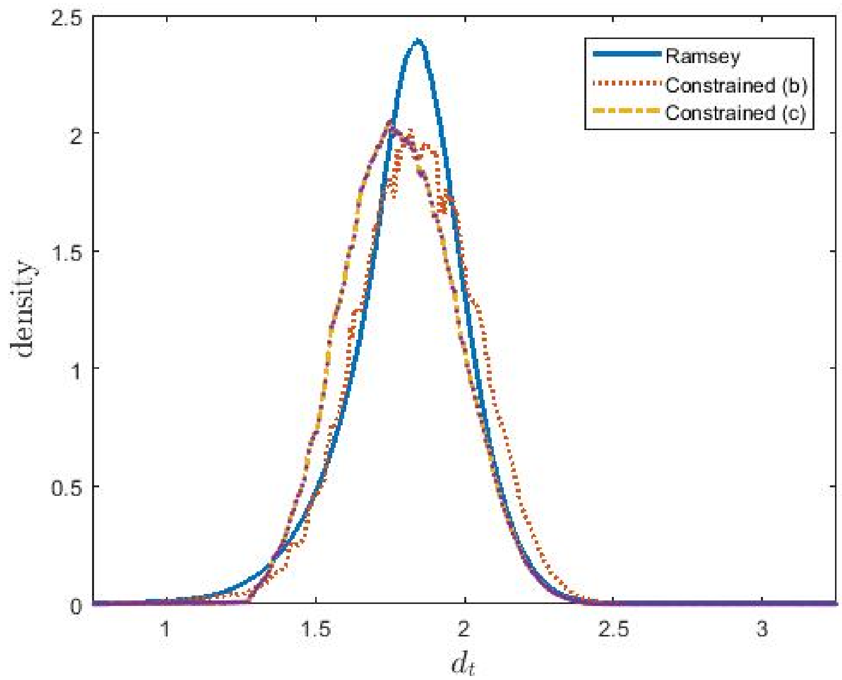


Table 2.2: External debt levels for different equilibria

Ramsey(Definition 2)	13.12%	
	Equilibrium 1	Equilibrium 2
Unregulated(Definition 1)	12.37%	12.01%
Tax rule, median tax rate 2.7%(Definition 3)	13.11%	13.16%
Tax rule and signaling, median tax rate 2.0%(Definition 4)	13.08%	13.07%

External debt levels are normalized by GDP.

2.4 Capital Controls and Expectations of Fundamentals in Iceland

The key mechanism in my model is government's signaling of economic fundamentals and the private agent's learning from such signals. Is there evidence of such signaling and learning in the data? In this section, I provide empirical evidence from Iceland that expectations of fundamentals change with capital control announcements. Iceland's experience between 2008 and 2017 is especially suitable for the model setting of this paper: as a small open economy, the country suffered from nonfundamental runs on its currency and foreign debts and implemented capital controls to deter such runs and to restore confidence in it economy. The empirical section starts with a discussion on how I constructed a list of capital control announcements from narrative sources and proceeds to show evidence that forecasts of fundamentals respond to these announcements.

2.4.1 Capital Controls in Iceland

In October 2008, three of Iceland's major banks, accounting for 85% of the country's commercial banking assets, failed within a few weeks and inflicted financial damages equal to about 7 times Iceland's GDP[1] on creditors, shareholders and depositors. Following this unprecedented financial collapse, there were significant downward pressures on the Icelandic Krona as capital flows rapidly out of the country. Rapid exchange rate depreciations are especially dangerous for Iceland because a large fraction of households and firms in the country earn income in the local currency but owe debt in foreign currency. The Icelandic government, in consultation with the International Monetary Fund (IMF), decided to impose strict regulations on capital outflows starting in November 2008: among other things, foreign carry-traders and domestic investors were forbidden to convert their Krona-denominated assets to foreign currency and to take their funds abroad. In the following years, several subsequent measures were announced to address potential loopholes. After concerns of capital outflows subsidized and pessimistic sentiments of the country's currency dissipated, Iceland gradually lifted its capital controls: a comprehensive plan for capital account liberalization was announced in June 2015, followed by step-by-step implementation until the last controls in place were removed in early 2017.

I use Iceland's experience during the global financial crisis because I think it is a good real-world example of the current model setting. First, Iceland is a small open economy with a liberal capital account during normal times; capital controls were implemented only in times of excessive and destabilizing capital outflows. In the current model, Schmitt-Grohe and Uribe(2018) have shown that the Ramsey-optimal policy is one in which the policymaker is committed to imposing capital controls at times of capital outflow. Second, the runs on Iceland's currency and foreign debts were triggerd by pessimistic sentiments about the country's economy; in the model, pessimistic sentiments are the reason agent underborrows in equilibrium to insure against a self-fulfilling crisis. Lastly, Iceland's capital controls were successful in arresting the rapid depreciation of the Krona and preventing further financial

[1]See Benediktsdottir, Eggertsson and Porarinsson(2017) for a detailed account and analysis of the failure of the Icelandic banking system in late 2008.

collapses; in the model, I assumed the government possesses superior information about economic fundamentals and conceived it as sensible real-world regulator capable of achieving intended policy objectives.

Using the IMF's Annual Report on Exchange Arrangements and Exchange Restrictions(AREAER) as my primary source, supplemented with announcements from the Icelandic government and the central bank of Iceland as well as news articles, I construct a list of all capital controls and related macroprudential measures in Iceland and their announcement dates between 2008 and 2017 by careful reading of these narrative sources. The list of policy measures is presented in Table 2.3. Relevant texts in original sources underlying the compilation of Table 2.3 are provided in Appendix B.B.

Table 2.3: Capital controls and related prudential measures in Iceland, 2008 - 2017

Measure	Announcement date	Source(s)
A comprehensive package of capital control measures were announced in conjunction with IMF loan, effectively closing the country's capital account entirely	11/17/2008	AREAER(2009), PM
Exporters were required to invoice and collect payments for exports in convertible foreign currency	4/1/2009	AREAER(2009)
Time limit of resident's repatriation of foreign currency extended	9/11/2011	AREAER(2011)
Limit placed on resident's foreign exchange purchase to buy real estate abroad	9/11/2011	AREAER(2011)
A few exemptions from previous capital control measures rescinded	3/13/2012	AREAER(2012)
Prohibition of purchase of foreign currency for payment of bond principal	3/13/2012	AREAER(2012)
Certain CBI exemptions will be granted only after consultation with officials	3/9/2013	AREAER(2013)
Certain dividend payment and purchase of securities abroad require CBI approval	4/3/2013	AREAER(2013)
Some restrictions on foreign exchange transactions lifted for residents and nonresidents	4/3/2013	AREAER(2013)
Announcement of a comprehensive plan for capital account liberalization, notwithstanding an associated stability tax	6/8/2015	CBI
CBI foreign currency auction announced, in which the Bank offers to buy offshore Kronur	5/25/2016	CBI
Capital controls on household and businesses lifted	10/21/2016	CBI
Remaining controls lifted, allowing pension and investment funds to invest abroad	3/12/2017	CBI,PM
CBI reached agreement with offshore holders of frozen krona-denominated assets	3/12/2017	CBI,PM

AREAER: IMF's Annual Report on Exchange Arrangements and Exchange Restrictions. PM: Icelandic Prime Minister's office. CBI: Central Bank of Iceland.

2.4.2 Using Capital Controls to Improve Icelandic GDP Nowcast

In this section, I use a conventional econometric model to nowcast Icelandic quarterly real GDP between 2008 and 2017. The nowcasts are my preferred measure of expectation of economic fundamentals and the data series used to produce the nowcasts represents the forecaster's information set. I add the capital control dummy variable constructed earlier to the forecaster's information set and show that it improves forecasting precision in real-time.

First, I briefly discuss time-series data used to form nowcasts of Icelandic quarterly real GDP growth. All categories of economic data typically included in a GDP-nowcasting model are used here and divided into six blocks: labor, trade, industrial production/sales, survey, monetary and financial.[2] All series are monthly data from January 2008 to December 2017. Capital control measures were announced during most of the years in the sample period.

The econometric framework in Giannone, Reichlin and Small(2008), widely used by central banks in advanced economies, is adopted to produce real-time nowcasts of quarterly Icelandic real GDP growth in a ten-year period between 2008 and 2017. Capital control measures are then added to the information set and they are shown to improves nowcast accuracy.

When capital outflows and nonfundamental runs on foreign debts are a major concern for the Icelandic economy, capital control measures help the forecaster obtain a more precise nowcast of GDP growth. Figure 2.4 plots Icelandic quarterly GDP growth rates with its nowcast at the end of the current quarter. As can be seen, the model does reasonably well in delivering a real-time assessment of current economic conditions. Figure 2.5 proceeds to show the mean forecast error reduction of each data block (at the end of the first month of the quarter)[3]. This exercise allows for the measurement of the information content of capital controls relative to other economic data series. In terms of forecast error reduction, Industrial production and capital controls contains the most important information, followed by income, and monetary statistics. Survey and financial variables have negligible effects on the nowcast.

[2]Table B1 in the appendix provides details of the data series. Each series is typically released at the same point in time in a given month, and hence Table B1, as a calendar of data release, also gives the order in which data enters into the nowcast model.

[3]Here I present the forecast error reduction in percentage of GDP growth rate to allow for a more straightforward interpretation. The time-series econometrics literature usually reports these in Mean-Squared Forecast Error(MSFE) normalized by the variance of the series, and I follow this convention in the appendix.

Figure 2.4: Nowcasting Icelandic real GDP growth

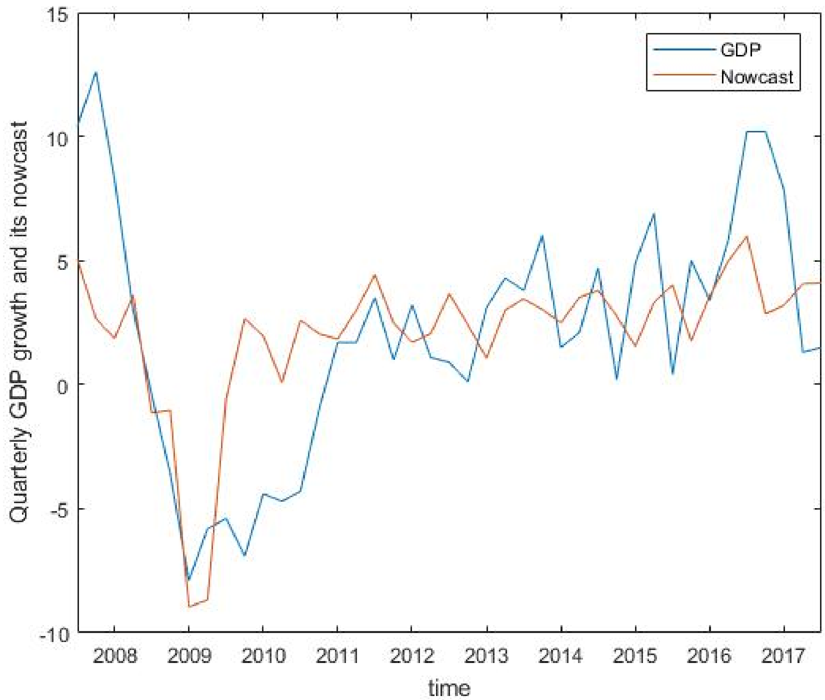


Table 2.4: Capital control announcement and forecast error reduction(FER)

Mean GDP growth	std. GDP growth	FER,1st month	FER,2nd month	FER,3rd month
2.10%	4.90%	1.33%	0.36%	0.80%

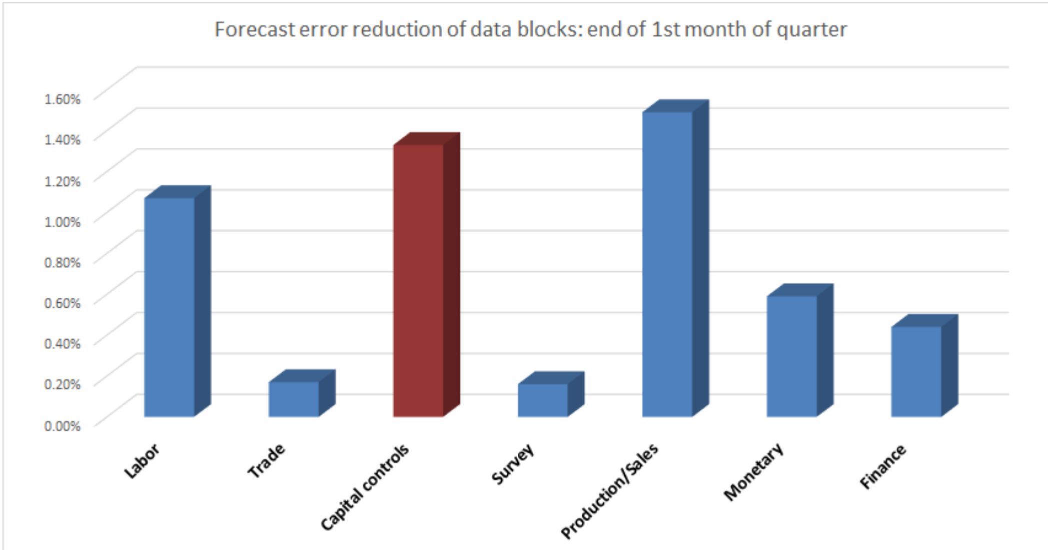
Our sample period is between 2008Q1 and 2017Q4.

Table 2.4 puts the magnitude of the information conveyed by capital controls in context. During my sample period, Icelandic real GDP growth averages 2.1% with a standard deviation of 4.9%. After capital control measures are included in the forecaster's information set, the nowcast of current quarter real GDP growth at the end of a given month becomes more accurate by 0.36%-1.33% in real-time, depending on which month in the quarter is considered.

2.5 Conclusion

This chapter explores the role of capital controls in actively signaling important information about fundamentals in a small open economy setting where pessimistic views about the value of collaterals lead to self-fulfilling financial crisis and multiple equilibria. In this envi-

Figure 2.5: Mean forecast error reduction of different economic data series



ronment, the private agent engages in excessive precautionary savings as a way to self-insure. When the policymaker signals information about future fundamentals through capital controls, the private agent learns from the signal, becomes less uncertain about future income and decreases precautionary savings, enhancing the efficacy of capital controls in eliminating equilibria with underborrowing. Empirically, I provide evidence that expectations of fundamentals change with capital control announcements in Iceland, a small open economy experiencing nonfundamental runs on its currency and foreign debts during the global financial crisis.

This chapter has clear policy implications for the role of capital controls in signaling about fundamentals. Since signaling enhances policy efficacy in an environment with equilibrium underborrowing, macroprudential authorities should make active use of it when deploying capital controls. Specifically, authorities should clearly communicate the nature of the policy rule used to determine capital control tax rates. These implications stand in contrast to results in the first chapter, where the role of information revelation is studied in a setting with equilibrium over-borrowing, the usual focus in the literature. In this alternative setting, signaling conveys valuable information about the collateral constraint, but also decreases precautionary savings precisely when such savings mitigate the pecuniary externality. Hence, signaling increases the severity of financial crisis in the model and has an ambiguous overall effect on welfare. Depending on the strength of different mechanisms, macroprudential authorities may or may not want to convey information about fundamentals through policy. In sum, whether policy intentions should be communicated clearly or not depends critically on what the capital controls are used for: a situation where preventive inflow controls are used to address over-borrowing and building-up of financial risks is very different from a situation where outflow controls are used to address ongoing capital outflows and nonfundamental runs on the financial system.

CHAPTER III

Expansionary Fiscal Austerity: New International Evidence

3.1 Introduction

A country engages in fiscal consolidation programs, increasing taxes or cutting government expenditures, when the national debt level is deemed high enough to influence the ability of the country to borrow in the future or to prevent it from undertaking necessary public spending programs. If the need for fiscal consolidation arises when the economy is at relative economic stagnation or decline, policymakers usually worry that fiscal consolidation efforts would become an additional drag on aggregate demand. It is therefore important to understand the output or consumption costs of fiscal austerity in order to weigh it against the benefit of reducing national debt. The expansionary fiscal contraction (EFC) hypothesis states that fiscal austerity can increase, or at least not decrease output or consumption when a country is under heavy debt burdens because it sends positive signal about the countrys solvency situation and long-term economic wellbeing. If this hypothesis is true, the cost of austerity relative to its benefit will be low if debt burden is high enough, and more austerity programs should therefore be undertaken.

This chapter seeks to bring new empirical evidence to bear on the subject of expansionary austerity by producing a new model-based definition of a high-debt regime, using a newly constructed cross-country narrative dataset and employing a new econometric methodology. Empirical results will depend crucially on how one defines when the debt level is high enough for austerities to have anti-Keynesian effects and on how one defines austerities. In this chapter, I use a calibrated model of expansionary austerity to produce a new definition of a high-debt regime for each country in my sample, and I use this definition along with conventional cutoff debt levels. I consider two alternative definitions of austerity: fiscal consolidations from the reading of narrative records, a direct measure, and structural shocks from identified Vector Auto-Regression(VAR), an indirect measure. For the first definition, I use a new source of cross-country narrative dataset constructed by the Fiscal Affairs department of the International Monetary Fund. For the second definition, I employ a relatively new econometric approach, the proxy structural VAR approach, which combines the attributes of two leading empirical methodologies in this literature.

Related Literature A large empirical literature focuses on the macroeconomic effects of fiscal policies. One branch of this literature identifies the motivation of fiscal reforms from careful examination of narrative records, such as legislative documents, news articles and presidential speeches, and uses these exogenous fiscal changes to estimate fiscal multipliers. Ramey and Shapiro (1998) and Romer and Romer (2010) are leading examples of narrative studies of U.S. fiscal policy. Researchers have also applied this approach to other countries: Devries et al. (2010) for OECD countries, Cloyne (2013) for the United Kingdom and Hayo and Uhl (2014) for Germany. Most recently, Alesina et al.(2016) extends the Devries et al.(2016) studies by focusing on detailed composition of a multi-year fiscal plan. Alesina et al. (2017) extended the Devries sample to 2009-2013, a period when plenty of consolidation took place. One definition of fiscal austerity in this paper relies on Dabla-Norris and Lima(2018), a source of quarterly narrative fiscal data for OECD countries.

Another branch of this literature, most notably Blanchard and Perotti(2002), focuses on the identification of exogenous fiscal shocks in VAR systems. Under plausible identifying assumptions, fiscal multiplier is the peak or average impulse response of output or consumption to a structural shock of fiscal variables. VAR estimates of the fiscal multiplier, however, differ substantially from narrative estimates. Hence, a number of papers attempt to reconcile this difference using various methodologies: Ramey(2010) pointed out that VAR shocks misses the timing of the news announcements; Mertens and Ravn(2013, 2014) developed the proxy structural VAR(PVAR) approach: a structural VAR with narrative shocks as instruments to help with identification. The second definition of fiscal austerity in this paper relies on the PVAR methodology.

Policy-oriented research in this literature focuses on deficit-driven fiscal consolidations and asks the following questions: what is the output effects of fiscal consolidation? When is fiscal austerity programs more likely to succeed? Is there such a thing as expansionary austerity? Perotti (1999) and Sutherland (1997) provided theoretical models in which fiscal austerity programs can increase consumption when debt burden is at a perilously high level. Alesina and Perotti(1996) provides preliminary empirical evidence in this direction. Recent studies on the subject include Blanchard and Leigh(2013), Guajardo, Leigh and Pescatori(2014) and House, Proebsting and Tesar(2015). In general, studies using data prior to 2009 show mixed or supportive empirical evidence of expansionary austerity, while these using data since 2009 tend to show the opposite.

This chapter is organized as follows. Section 3.2 reviews a theoretical model of expansionary austerity and calibrate the model to deliver a definition of high-debt regime for each country in my sample. Section 3.3 introduces a new source of narrative data, checks the quality of the data in a VAR exercise and presents empirical results using the narrative series as a direct measure of austerity. Section 3.4 uses structural shocks recovered from a PVAR as an indirect measure of austerity and presents another set of empirical results. Section 3.5 concludes.

3.2 A Model-based definition of high-debt regime

A study of expansionary austerity usually starts by defining when debts are "too high". The literature has so far used empirical debt thresholds advocated by policy institutions. In this section, I provide a way of defining high-debt regimes based on Sutherland(1997)'s theoretical model of expansionary austerity. I calibrate the model to provide a cutoff debt-to-GDP value for each country in my sample. I briefly discuss the model below before presenting the cutoff values for each country.

The model is in continuous time and the environment features a finitely-lived representative consumer and a government. Let B_t be the stock of per capita public debt, F deficit spending and r the interest rate paid on public debt. The evolution of government debt is governed by a Brownian motion, where W_t is a standard Wiener process and σ scales up the variance:

$$dB_t = rB_t dt + F_t \tag{3.1}$$

$$F_t = \sigma dW_t \tag{3.2}$$

This process means the government routinely overspends, and hence it engages in periodic fiscal austerity programs to satisfy its intertemporal budget constraint. Stabilization programs take the following form: when the stock of debt, B_t, is larger than some crisis level

U, the government imposes a one time lump-sum tax of size T to bring down the debt level to U-T. Symmetrically, when $B_t < L$, a one time lump-sum transfer of the size T brings the debt level up to L+T.

The consumer is finitely-lived and she discounts future utility with a Poisson death rate, θ, in addition to the interest rate. Hence, she maximizes

$$E_0 \int_0^\infty u(C(t)) \exp(-(r+\theta)t) dt \tag{3.3}$$

subject to the following flow budget constraint:

$$dA_t = [y - C_t + (r+\theta)A_t]dt + F_t - \delta(t)T \tag{3.4}$$

In the budget constraint, y is fixed per-period income and A_t household wealth in the form of bond holdings. Government deficit spending, F_t, is assumed to be a transfer to the consumer which increases her stock of wealth. $\delta(t)$ is an indicator that takes on the value of 1 when there is a stabilization tax, 0 during "normal times" and -1 when there is a stabilization transfer. Like usual deficit spendings, austerity programs change the wealth of households. S, the expected discounted future tax liabilities from possible austerity programs, is defined as follows:

$$S_t = E_t \int_t^\infty \delta(\tau) T \exp(-(r+\theta)(\tau - t)) d\tau \tag{3.5}$$

S_t is a function of current stock of debt, B_t, since the possibility of future stabilization depends on how close B_t is to the critical values U and L. Rewrite S as the sum of expected future tax liabilities from t to Δt and from Δt to ∞, and let Δ_t approaches dt, assuming stabilizations do not take place during this infinitely-short time period, and differentiate S, I obtain:

$$E_t dS = (r+\theta) S dt \tag{3.6}$$

Applying Ito's lemma to the function $S(B_t)$, another equation is obtained:

$$E_t dS = [rBS'(B) + \frac{\sigma^2}{2} S''(B)]dt \tag{3.7}$$

Combining equations 3.6 and 3.7, we have a system of second order differential equations in $S(B_t)$. Solution to the system is obtained with two initial conditions given by government behaviors at the two critical values, U and L:

$$S(U - T) = S(U) - T \tag{3.8}$$

$$S(L+T) = S(L) + T \tag{3.9}$$

Having characterized the solution for S, I return to the consumer's problem. With quadratic utility, intertemporal consumption smoothing implies a consumption rule of the following:

$$C_t = y + (r+\theta)[A_t - S(B_t)] \tag{3.10}$$

Changes in consumption depend on changes in asset position and expected future tax liability from possible stabilization programs. An increase in deficit spending, whether a spending hike or a tax break, increases household asset one for one as it is assumed to be a direct transfer. However, deficit spending increases total stock of debt and hence increases S, the expected future taxes from austerity. In other words, the conventional Keynesian effect of fiscal stimulus increases consumption through changing consumer's permanent income, but the worry of impending stabilization taxes decreases consumption. The precise magnitude of the second effect depends on how close the current debt level is to the critical levels and on the first derivative of the function S.

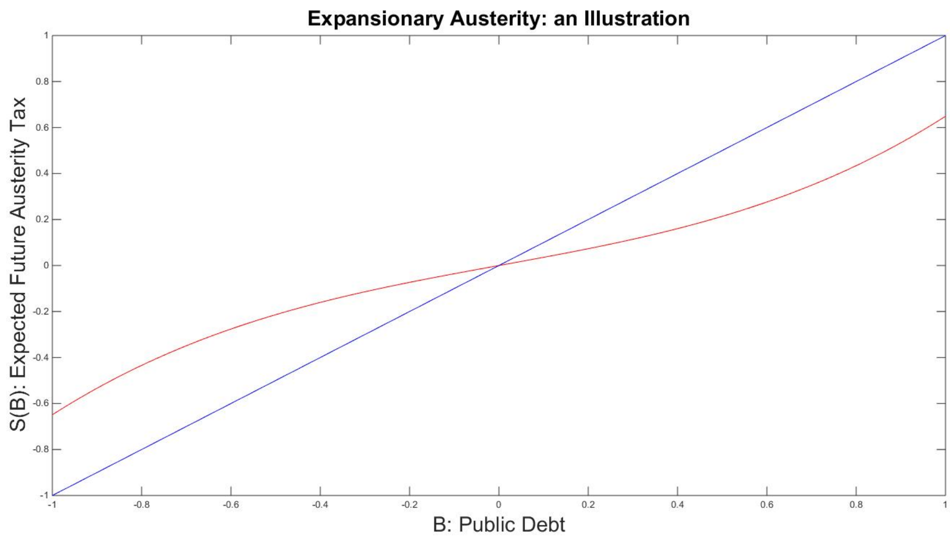
This model is capable of delivering a cutoff level of national debt beyond which austerities can increase consumption as the decrease in expected stabilization taxes outweighs the decrease in permanent income. This cutoff level, B^*, is given by:

$$S'(B^*) = 1 \tag{3.11}$$

At B^*, the two effects would exactly cancel out. When $B^* < B$, the conventional Keynesian effect dominates and hence it is impossible to identify the anti-Keynesian effect. When $B^* > B$, the model predicts that austerity should increase consumption.

In figure 3.1, I plot the function S against the 45-degree line for a set of parameter values. B^* depends on T, the expected size of stabilization tax, σ, the variance of the government debt accumulation process, r, the real interest rate, θ, the Poisson death rate of households, and U and L, the exogenous debt limits. Intuitively, U and L determine how far debt level in the economy is from triggering austerity programs; given how far the economy is from U and L, σ and r then determine how fast it gets there; T is the expected loss/gain of wealth once the economy gets to U and L. The Ricardian equivalence result does not hold here because the consumer finitely lived, so θ matters because she cares less about a tax that will likely come after her death than a tax that is coming at some point during her lifetime. In figure 1, B^* is the point at which the derivative of S is parallel to the 45-degree line. For this set of parameter value, $B^* = 0.853$. If one chooses the six parameters to target data in a country, the model will produce a unique cutoff value B_i^* for this country.

Figure 3.1: S(B) under the following parametrization: $\theta = 0.1$, r = 0.05, $\sigma = 0.2$, U = 1, L = -1, T = 0.3



For all 17 OECD countries in the empirical studies of this paper, I calibrate the model at annual frequency using data between 1981 - 2009. All parameters are a percentage of GDP whenever applicable. The OECD advocates a prudential debt target of 70-90% for advanced economies, but only 50-70% for Eurozone countries since these countries lack monetary independence. Hence, I set U = 0.6 for Eurozone countries and U = 0.8 otherwise. r is calculated as the sample average of annualized return on 10-year government bond, θ the inverse of the sample average of life expectancy at birth and σ the variance of government primary balance from the IMF's Historical Public Finance dataset(Mauro et al.(2015)).

T is calculated using the narrative fiscal series in Devries et al. (2010), which provides the size of both tax-based and spending-based austerity programs at annual frequency. I calculate T as the average size of an austerity program, some of which spans across multiple years. In the model, T is the size of a one-time tax which constitutes the entire stabilization program, so its empirical counterpart is also chosen to be an entire program. For instance, if a country reduced its budget deficit by 3% of GDP in each year between 1983 and 1986 as prescribed in a legislation passed in 1982 and by 4% of GDP in 1996 as prescribed in a legislation passed in 1995, then there are two austerity programs in the sample with respective sizes of 9% and 4%. Accordingly, T is set to 0.065, the average size of these two programs. All parameter values used for each country are shown in Table C1 in Appendix C.

Table 3.1 below displays the value of B^* for each country in the sample. My model-based definition of a high-debt regime for country i at time t, D_{it}, is as follows: $D_{it} = 1$ if $B_{i,t} > B^*$, $D_{it} = 0$ otherwise.

Table 3.1: Critical debt level B^*, % of GDP

Country	AUS	AUT	BEL	CAN	DNK	FIN	FRA	DEU	
B^*	78.9	58.9	56.1	75.9	76.7	54.1	59.5	58.1	
Country	**IRE**	**ITA**	**JPN**	**NLD**	**PRT**	**ESP**	**SWE**	**GBR**	**USA**
B^*	56.4	54	79.1	57.1	58.3	57.4	77.2	78.8	79.2

3.3 Testing the EFC hypothesis with new narrative data

In this section, I use a new source of cross-country quarterly narrative data of tax-based consolidations to test the EFC hypothesis. I briefly introduce the narrative dataset and perform a quality check of the data using panel PVAR before presenting my main empirical results using two alternative definitions of a high-debt regime, a model-based definition from the last section and a conventional threshold definition.

3.3.1 Overview of the narrative data

Cross-country empirical studies of fiscal consolidation have suffered from a lack of data sources: quarterly narrative series are only available for a number of advanced economies, such as Romer and Romer(2010) for the United States and Cloyne(2013) for the United Kingdom. Cross-country narrative dataset was only available at annual frequency(Devries et al.(2010)). In this section, I use a newly-constructed quarterly panel dataset of narrative tax series to study expansionary austerity.

The narrative dataset is compiled by the fiscal affairs department at the International Monetary Fund(IMF) and described in Dabla-Norris and Lima(2018). This dataset contains detailed information on the expected revenue impact, motivation, announcement and implementation dates of nearly 2,500 tax measures of fiscal consolidation across 10 OECD countries between 1983 and 2009. The authors rely on contemporaneous primary sources including budget documents, reports from the Ministry of Finance and tax authorities, technical reports and notes produced during legislative procedures, and discussions on tax reforms during parliamentary debates. When necessary, these sources are complemented by information from secondary sources such as IMF staff reports, OECD Economic Surveys, Stability and Growth Pact documents, and news articles on tax reform from national newspapers or from the International Bureau of Fiscal Documentation(IBFD).

3.3.2 Quality check of the narrative data

Before proceeding to the main empirical results, I perform a quality check of the narrative data by extending results in Mertens and Ravn(2013) to a cross-country setting. Critics of the narrative approach are often skeptical of the quality of narrative data because the construction of such data relies on the reading of a large amount of narrative sources by a few authors to determine motivations and intentions behind a large number of policy changes. Therefore, the produced datasets depend heavily upon subjective judgment calls made by authors. Hence, a quality check is necessary before using the series to study the main research question of this paper.

My quality check takes the form of examining the responses of macroeconomic and fiscal variables to changes in personal income tax(PIT) rate and corporate income tax(CIT) rate for a panel of OECD countries. Mertens and Ravn(2013) document such responses for the United States in a PVAR setting after constructing narrative series for PIT and CIT changes. The narrative dataset in Dabla-Norris and Lima(2018) provides granular information on tax-based fiscal consolidations, especially on tax rate and tax base changes for a panel of OECD countries. The dataset can be seen as an extension of Mertens and Ravn(2013)'s work on narrative data to more countries. Hence, a natural quality check is to extend the PIT and CIT results for the United States to these countries.

Since I do not have a long enough time series to carry out a PVAR for each country, I extend the methodology to a panel setting, pooling estimates of structural parameters(elasticities) while estimating reduced-form VARs for each country. My procedure is divided into four steps and described below:

In the first step, I estimate country-specific reduced-form VARs: consider the following model for $X_{i,t}$ for each country i,

$$X_{i,t} = A_{0,i} + \Sigma_{p=0}^{P} A_{p,i} X_{i,t-p} + u_{i,t} \tag{3.12}$$

Equation 3.12 is estimated for each country to obtain country-specific reduced form VAR coefficients $A_{0,i}$ and $A_{p,i}$. p is determined by standard lag-order selection criterion. I obtain country-specific reduced-form shocks, $u_{i,t}$, in this step.

In the second step, I pool estimates of structural parameters of the system: let $u_t = [u_{1,t}, u_{2,t}, ...]'$ be a vector of stacked country-specific reduced-form shocks and $m_t = [m_{1,t}, m_{2,t}, ...]'$ be a vector of stacked narrative shocks. $\epsilon_{i,t}$ are structural shocks. I estimate the following PVAR model:

$$u_t = B\epsilon_t \tag{3.13}$$

Here, the structural errors satisfies $E[\epsilon_t] = 0$ and $E[\epsilon_t \epsilon_t'] = I$. Since $E[u_t u_t'] = BE[\epsilon_t \epsilon_t']B' = BB'$, and the sample analogue of $E[u_t u_t']$ is an n-by-n covariance matrix which provides $\frac{n(n+1)}{2}$ independent identification restrictions. There are n parameters in the original system, so the system is under-identified. The PVAR identification approach avoids imposing values of certain structural parameters and instead uses narrative shocks to obtain additional covariance restrictions. Consider the following partitioning of B and ϵ_t: $B = [\beta_1 \beta_2], \beta_1 = [\beta_{11}' \beta_{21}']', \beta_2 = [\beta_{12}' \beta_{22}']'$, $\epsilon_t = [\epsilon_{1t} \epsilon_{2t}]$ and $\Sigma_{mu'} = [\Sigma_{mu'1} \Sigma_{mu'2}]$. Let m_t be an k-dimensional vector of narrative tax shocks, we have the following assumptions:

$$E[m_t \epsilon_{1t}] = \Phi \tag{3.14}$$

$$E[m_t \epsilon_{2t}] = 0 \tag{3.15}$$

Namely, the narrative tax shocks are positively correlated with the structural tax disturbances they seek to capture, but are uncorrelated with other structural disturbances. Combining 3.14 and 3.15 with 3.13, the identification assumptions implies the following restrictions on elements of B:

$$\Phi \beta' = \Sigma_{mu'} \tag{3.16}$$

$$\beta_{21} = (\Sigma_{mu'1}^{-1} \Sigma_{mu'2})' \beta_{11} \tag{3.17}$$

These additional restrictions allows the structural VAR to be just-identified. I obtain common structural parameters(elasticities) B_i in this step.

In the third step, I compute country-specific impulse response functions(IRFs) using the vector of country-specific reduced form parameters $\Omega_i^d = [A_{0,i}, A_{1,i}, ..., A_{p,i}]$ and common structural parameters in the matrix B.

In the last step, I compute the average IRFs and their bootstrap confidence intervals: the average IRFs are calculated simple arithmetic averages of the country-specific impulse response functions. The confidence intervals of the average IRFs is computed by an amended wild bootstrap procedure designed specifically for this setting. The algorithm is detailed in the computational appendix.

Figure 3.2 shows responses of selected variables to a 1% cut in average personal income tax rate(APITR). 95% bootstrap confidence intervals are displayed alongside point estimates of the impulse responses. I find that APITR remains below the expected level prior to the shock and it converges to its pre-shock level in the longer run. The tax-rate cut sets off an increase in the personal income tax base in the short-run, but the increase moderates in the longer run. The tax-rate cut provides a short-run stimulus to output: a 1 percentage point decrease in APITR leads to a peak increase of output of around 1 percent, which occurs three quarters after the cut. The confidence intervals indicate a significant increase in economic activity within a 6-quarter window after the tax cut. Government spending also increases following the cut in APITR. These results are broadly in line with results in Mertens and Ravn(2013), but differ slightly in magnitude and in timing of the responses, since their study focuses on the United States and this exercise extends the analysis to a panel of OECD countries.

Figure 3.2: Impulse responses to a 1 percent cut in average personal income tax rate

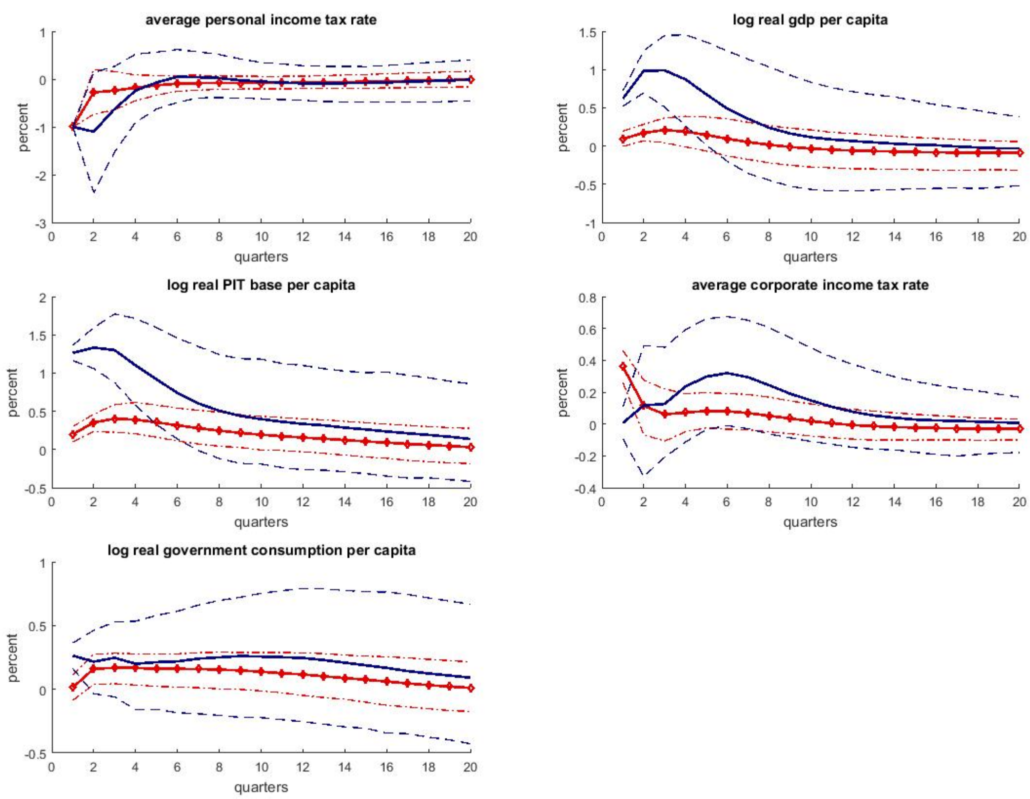
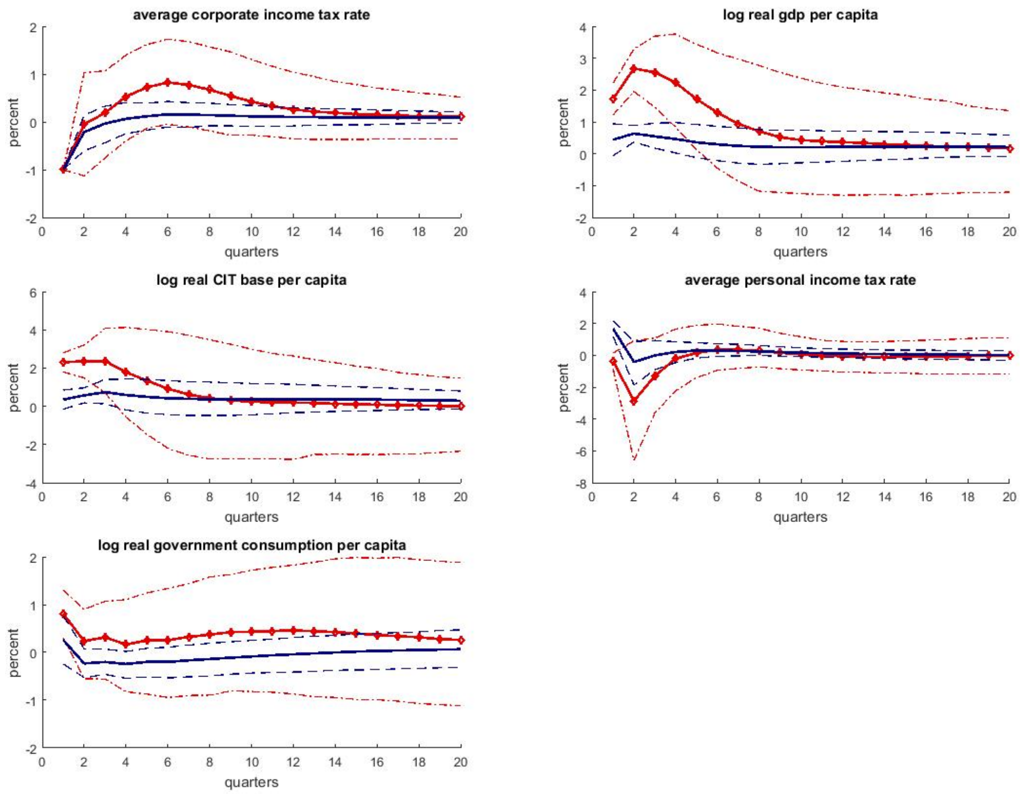


Figure 3.3 shows responses of selected variables to a 1% cut in average corporate income tax rate(ACITR). The cut leads to a large and significant increase in corporate income tax base in the short-run. The output effects of ACITR cuts are significant and substantial for the first 6 quarters. Combining the results for ACITR and the corporate income tax base, the cut in ACITR appear to be self-financing even in the longer run. Again, these cross-country results are qualitatively similar to what Mertens and Ravn(2013) found for the United States.

Figure 3.3: Impulse responses to a 1 percent cut in average corporate income tax rate



3.3.3 Empirical results

This section presents my main empirical results. As the narrative approach identifies exogenous fiscal changes not motivated by stabilizing the economy over the business-cycle, I use the narrative shocks as a direct measure of austerity and run the following panel regression:

$$\Delta Y_{it} = \alpha_i + \beta_t + \gamma_2 \epsilon_{it}^T + \theta_2 D_{it} \epsilon_{it}^T + \omega_{it} \tag{3.18}$$

where Y_{it} is log of GDP per capita, ϵ_{it}^T tax austerity shocks from Dabla-Norris and Lima(2018) and D_{it} debt regime dummy that equals 1 in a state of high-debt and 0 otherwise. Regression results are reported for all tax changes, tax rate changes and tax base changes, respectively. Table 3.2 presents results for equation 3.18 using model-based definition of high-debt regime. As expected, fiscal consolidation programs based on tax increases slow down output growth. However, when the economy is in high-debt regime, an additional expansionary effect of tax consolidations is present. This additional effect is driven entirely by changes in tax rate: the second column shows that a 1 percent increase in taxation by raising tax rates is associated with a 54-basis-point decrease in output at all times, yet it is associated with an additional 75-basis-point increase in output in a high-debt regime. Both effects are statistically significant. Importantly, the net effect of a tax-hike by raising tax rate in a high-debt regime is expansionary.

Table 3.2: Expansionary Austerity: Narrative shocks

	GDP Growth Coef./SE	GDP Growth Coef./SE	GDP Growth Coef./SE
Tax Shock	-0.6023***		
	(0.1685)		
Tax Shock*Dummy	0.2586		
	(0.2892)		
Tax Rate Shock		-0.5403***	
		(0.1871)	
Tax Rate Shock*Dummy		0.7564**	
		(0.3805)	
Tax Base Shock			-0.2630
			(0.2174)
Tax Base Shock*Dummy			-0.3782
			(0.3592)
Sample Size	1215	1215	1215

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Standard errors in parentheses.

Note: All regressions include a constant and a full set of country and year dummies. Standard errors are cluster-robust.

Table 3.3 presents the same set of empirical results using an alternative definition of a high-debt regime: D_{it} is equal to 1 if the country's debt-to-GDP ratio is above the 80 percentile of its historical empirical distribution. This definition is commonly used in the literature(Perotti(1999)) and it can be thought of as a Reinhart and Rogoff(2008) type debt trigger. Again, when the economy is in the high-debt regime, an additional expansionary effect is present. The additional effect of tax consolidations is driven entirely by changes in tax rate: the second column shows that a 1 percent increase in taxation by raising tax rates is associated with a 63 basis point decrease in output at all times, but it is associated with an additional 57 basis point increase in output in a high-debt regime. Both effects are again statistically significant. Although the net effect of a tax-hike by raising tax rate during bad times is not expansionary under this definition of a high-debt regime, it is hardly contractionary in terms of output losses.

Table 3.3: Expansionary Austerity: Narrative shocks, alternative regime

	GDP Growth Coef./SE	GDP Growth Coef./SE	GDP Growth Coef./SE
Tax Shock	-0.7321***		
	(0.1972)		
Tax Shock*Dummy	0.4207*		
	(0.2740)		
Tax Rate Shock		-0.6310***	
		(0.2240)	
Tax Rate Shock*Dummy		0.5742**	
		(0.3230)	
Tax Base Shock			-0.6051**
			(0.3176)
Tax Base Shock*Dummy			0.2930
			(0.3806)
Sample Size	1215	1215	1215

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Standard errors in parentheses.

Note: All regressions include a constant and a full set of country and year dummies. Standard errors are cluster-robust.

In sum, using quarterly narrative data on fiscal consolidations, I find that austerity programs which increase tax rates during bad times do not necessarily cause significant output losses, and can potentially be expansionary. This finding is robust to how one defines the critical debt level beyond which an anti-Keynesian effect is expected to be present.

3.4 Testing the EFC hypothesis with VAR structural shocks

In this section, I use structural shocks estimated from an identified VAR to test the EFC hypothesis. Structural fiscal shocks recovered from a Proxy structural VAR(PVAR), a relatively new empirical methodology in this literature, serves as an indirect measure of austerity. I discuss data and the PVAR identification assumptions before presenting main empirical results using two alternative definitions of high-debt regime.

3.4.1 Data

My sample consists of annual data for 17 OECD countries between 1978 and 2009[1]. These countries are: Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Ireland, Italy, Japan, Netherlands, Portugal, Spain, Sweden, the United Kingdom and the United States. Y_t and T_t are *Gross Domestic Product* and *Tax Revenue* from OECD statistics. G_t is *Government Expenditure* from Mauro et al.(2015), the most comprehensive source of fiscal flows and stocks where I also take debt-to-GDP ratios. All three variables in the SVAR are in logs, per capita, real and in dollars. The narrative fiscal series are from Devries et al(2014), where the authors document the exact sources and methodologies underlying the construction of discretionary changes in taxes and spending, drawing extensively on policy documents and reports to identify the motivation of such changes. Guajardo, Leigh and Pescatori(2014) use this dataset to study expansionary fiscal contractions.

3.4.2 Structural VAR specification

Since my time series is short relative to the number of parameters, I consider the following panel PVAR model for $X_{i,t} = [T_{i,t}, G_{i,t}, Y_{i,t}]'$ after taking out country specific deterministic time trend and demeaning $X_{i,t}$:

$$X_{i,t} = A_1 X_{i,t-1} + ... + A_p X_{i,t-p} + u_{i,t} \tag{3.19}$$

This specification allows me to pool estimates of the lag coefficient matrices and hence reduce the total number of estimated parameters, while still having country-specific reduced form shocks.[2] Let $u_{i,t} = [u^T_{i,t}, u^G_{i,t}, u^Y_{i,t}]$ be reduced-form shocks and $\epsilon_{i,t} = [\epsilon^T_{i,t}, \epsilon^G_{i,t}, \epsilon^Y_{i,t}]$ structural shocks, I estimate the following system for each country i:

$$u^T_{i,t} = \theta_G \sigma_G \epsilon^G_{i,t} + \theta_Y u^Y_{i,t} + \sigma_T \epsilon^T_{i,t} \tag{3.20}$$

$$u^G_{i,t} = \gamma_T \sigma_T \epsilon^T_{i,t} + \gamma_Y u^Y_{i,t} + \sigma_G \epsilon^G_{i,t} \tag{3.21}$$

$$u^Y_{i,t} = \zeta_T u^T_{i,t} + \zeta_G u^G_{i,t} + \sigma_Y \epsilon^Y_{i,t} \tag{3.22}$$

[1]Final regressions are for the years 1981-2009, since I estimated the VARs with two lags and variables are first-differenced.

[2]Panel VAR estimation is carried out with Abrigo and Love(2015)'s package in STATA.

The structural errors satisfies $E[\epsilon_{i,t}] = 0$ and $E[\epsilon_{i,t}\epsilon'_{i,t}] = I$.

I discuss the PVAR identification strategy proposed by Mertens and Ravn(2014) for this system, which is based in part on assumptions from Blanchard and Perotti(2002), in which identification involves imposing certain values on parameters of the system. First and foremost, because of decision and recognition lags, it is presumed that discretionary responses of spending to cyclical movements of output is unlikely, and hence $\gamma_Y = 0$. Second, the literature usually remains agnostic about whether spending or tax decisions come first. This means one of θ_G and γ_T is set to zero and the other one can be estimated. Results are robust to this choice. Finally, θ_Y, the elasticity of tax revenue with respect to output, is calibrated to OECD estimates(See Giorno et al.(1995) for details of the calibration procedure). For instance, θ_Y is set to 2.08 for the case of the United States. The following decomposition is used in the calibration of θ_Y:

Let B be the tax base. θ_Y consists of a sum, across all tax types, of the elasticity of each type of tax with respect to its tax base times the elasticity of its tax base with respect to output, weighted by the share of the tax in total tax revenue:

$$\theta_Y = \frac{dT}{dY} = \frac{dT}{dB}\frac{dB}{dY} = \Sigma_i \frac{\frac{dT_i}{T_i}}{\frac{dB_i}{B_i}} \frac{\frac{dB_i}{B_i}}{\frac{dY}{Y}} \frac{T_i}{T} = \Sigma_i \eta_{T_i,B_i}\eta_{B_i,Y}\frac{T_i}{T} \tag{3.23}$$

The response of tax to output in this setting encompasses stabilization policy, so long as the policy is pre-ordained in the tax code. An extension of the duration of unemployment insurance when the economy is in a downturn is a good example of such an automatic-stabilizer.

The system of equations 3.20 - 3.22 can be written in matrix form as:

$$\begin{bmatrix} 1 & 0 & -\theta_Y \\ 0 & 1 & -\gamma_Y \\ -\zeta_T & -\zeta_G & 1 \end{bmatrix} \begin{bmatrix} u_t^T \\ u_t^G \\ u_t^Y \end{bmatrix} = \begin{bmatrix} \sigma_T & \theta_G\sigma_G & 0 \\ \gamma_T\sigma_T & \sigma_G & 0 \\ 0 & 0 & \sigma_Y \end{bmatrix} \begin{bmatrix} \epsilon_t^T \\ \epsilon_t^G \\ \epsilon_t^Y \end{bmatrix} \tag{3.24}$$

or more compactly, $Au_t = D\epsilon_t$. Therefore:

$$u_t = A^{-1}D\epsilon_t = B\epsilon_t \tag{3.25}$$

$$E[u_t u_t'] = BE[\epsilon_t\epsilon_t']B' = BB' \tag{3.26}$$

Since the sample analogue of $E[u_t u_t']$ is a three-by-three covariance matrix, it provides six independent identification restrictions. There are nine parameters in the original system, so the structural VAR will be just-identified if one imposes the three additional restrictions above. Mertens and Ravn(2014) provides identification restrictions by utilizing information from available narrative series of exogenous fiscal shocks. The original purpose of this approach was to reconcile the significant difference between estimates of the fiscal multiplier from the SVAR approach and from the narrative approach. Let m_t be the narrative tax shocks, and the assumptions are as follows:

$$E[m_t \epsilon_t^T] = \phi \tag{3.27}$$

$$E[m_t \epsilon_t^G] = 0 \tag{3.28}$$

$$E[m_t \epsilon_t^Y] = 0 \tag{3.29}$$

In words, the narrative tax shocks are positively correlated with the corresponding structural tax shocks, but uncorrelated with other structural shocks. Hence:

$$E[u_t m_t] = E[B\epsilon_t m_t] = E[B \begin{bmatrix} \phi \\ 0 \\ 0 \end{bmatrix}] = \phi \begin{bmatrix} \beta_{11} \\ \beta_{21} \\ \beta_{31} \end{bmatrix} \tag{3.30}$$

Thus, two independent identification restrictions are obtained:

$$\begin{bmatrix} \beta_{21} \\ \beta_{31} \end{bmatrix} = \phi^{-1} E[m_t \begin{bmatrix} u_t^G \\ u_t^Y \end{bmatrix}] = \beta_{11} E[m_t u_t^T]^{-1} E[m_t \begin{bmatrix} u_t^G \\ u_t^Y \end{bmatrix}] \tag{3.31}$$

This means two out of the three parameter restrictions in Blanchard and Perotti(2002) can be replaced. In particular, the calibrations of θ_Y is considered problematic and no longer imposed. $\gamma_Y = 0$ is still imposed. The PVAR system is just-identified with eight parameters and eight independent identification restrictions. The structural shocks, $\epsilon_{i,t} = [\epsilon_{i,t}^T, \epsilon_{i,t}^G, \epsilon_{i,t}^Y]$, are estimated for every country i and retrieved for use as an indirect measure of austerity.

As an illustration, I plot the structural fiscal shocks for Denmark in figure C1 in the Appendix. Between 1983 and 1986, Denmark implemented a large-scale austerity program involving actions on both the expenditure side, such as limits on public sector wages and social payments, and the revenue side, such as hikes in social security contributions, taxation of higher-yielding pensions and an increase in the maximum tax rates. The program was announced in 1982 with the formation of a new coalition government. As can be seen in the figure, the estimated structural tax and spending shocks from PVAR correspond relatively well with what happened during the period.

3.4.3 Empirical results

This section presents my second set of main empirical results. As the structural fiscal shocks from PVAR in the last section is uncorrelated with output, they are used as a measure of austerity. In section 3.3, the Dabla-Norris and Lima(2018) narrative dataset covers only changes in taxation. The structural fiscal shocks cover both changes to taxation and to government spending. I estimate the following set of panel regressions:

$$\Delta Y_{it} = \alpha_i + \beta_t + \gamma_1 \epsilon_{it}^G + \gamma_2 \epsilon_{it}^T + \omega_{it} \tag{3.32}$$

$$\Delta Y_{it} = \alpha_i + \beta_t + \gamma_1 \epsilon_{it}^G + \theta_1 D_{it} \epsilon_{it}^G + \gamma_2 \epsilon_{it}^T + \theta_2 D_{it} \epsilon_{it}^T + \omega_{it} \tag{3.33}$$

where ΔY_{it} is output or consumption growth. The first regression looks at the general relationship between output/consumption and the structural fiscal shocks, and the second regression interacts the fiscal shocks with regime dummies, D_{it}, to explore the presence of expansionary austerity. D_{it} is a debt regime dummy which equals 1 in a state of high-debt and 0 otherwise.

Table 3.4: Expansionary Austerity: Mertens-Ravn shocks

	Consumption Growth	Consumption Growth
	Coef./SE	Coef./SE
Tax Shock	-0.6821***	-0.8019**
	(0.1450)	(0.3997)
Spending Shock	0.2552***	0.3700**
	(0.0796)	(0.1598)
Tax Shock*Dummy		0.7720
		(0.9220)
Spending Shock*Dummy		-0.6880***
		(0.2174)
Constant	1.0190	0.8143
	(0.7701)	(0.9210)
Sample Size	116	116
R^2	0.5224	0.5363

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Standard errors in parentheses.

Note: All regressions include a full set of country and year dummies. Standard errors are cluster-robust.

Table 3.4 and table 3.5 present results for equations 3.32 and 3.33 using the model-based definition of high-debt regime. In general, increasing taxes or decreasing government spending reduces output and consumption, as expected. When the economy is in the high-debt regime, an additional expansionary channel of fiscal austerity is present: increasing taxes or decreasing government spending actually boosts output/consumption. This additional anti-Kenyesian channel is statistically significant for the effect of spending on consumption and for the effect of taxation on output. In table 3.4, cutting government spending by 1 percent decreases consumption growth by 37 basis point at all times, but boosts it by an additional 69 basis point in a high-debt regime. In table 3.5, increasing taxes by 1 percent lowers output growth by 75 basis point, but boosts it by an additional 72 basis point in a high-debt regime. In sum, when debt levels are perilously high, government spending cuts increase consumption, and tax hikes do not entail output losses.

Table 3.5: Expansionary Austerity: Mertens-Ravn shocks

	Real GDP Growth	Real GDP Growth
	Coef./SE	Coef./SE
Tax Shock	-0.5839***	-0.7488***
	(0.1932)	(0.2473)
Spending Shock	0.1460	0.1595
	(0.2512)	(0.1598)
Tax Shock*Dummy		0.7209***
		(0.2984)
Spending Shock*Dummy		-0.2064
		(0.4394)
Constant	0.8717***	0.8143
	(0.2252)	(0.9210)
Sample Size	105	105
R^2	0.8094	0.8149

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Standard errors in parentheses.

Note: All regressions include a full set of country and year dummies. Standard errors are cluster-robust.

Table 3.6 presents the same set of empirical results for consumption, using the alternative definition of high-debt regime. Under this definition, the additional anti-Kenyesian channel is statistically significant for the effect of taxation on consumption. Increasing taxes by 1 percent lowers consumption growth by 1 percent, but boosts it by an additional 1 percent in a high-debt regime. When debt levels are perilously high, tax hikes do not entail consumption losses.

Table 3.6: Expansionary Austerity: Mertens-Ravn shocks, alternative regime

	Consumption Growth	Consumption Growth
	Coef./SE	Coef./SE
Tax Shock	-0.6821***	-1.0382***
	(0.1450)	(0.3084)
Spending Shock	0.2552	0.2167***
	(0.0796)	(0.0558)
Tax Shock*Dummy		0.9925***
		(0.3606)
Spending Shock*Dummy		0.2603
		(0.2310)
Constant	1.0190***	0.8143
	(0.7701)	(0.9210)
Sample Size	105	116
R^2	0.5224	0.5497

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Standard errors in parentheses.

Note: All regressions include a full set of country and year dummies. Standard errors are cluster-robust.

In sum, using structural shocks recovered from a PVAR, I find that fiscal austerity programs do not necessarily entail significant output or consumption losses when the economy is under heavy debt burdens. These findings are generally in line with results from narrative data.

3.5 Conclusion

In this paper, I provide some empirical evidence in support of the Expansionary Fiscal Contraction(EFC) hypothesis: when a country's debt level is perilously high, tax-based austerity programs can be expansionary(increasing output or consumption), or at least not contractionary. This paper contributes to the empirical literature of this topic by employing a model-based definition of high-debt regimes and providing two alternative definitions of austerity: one definition is based on a new source of cross-country quarterly narrative fiscal data and the other definition is based on structural fiscal shocks estimated from a PVAR. My empirical results for consumption are robust to alternative definitions of high-debt regime but not to alternative definitions of austerity; my results for output are robust to both defi-

nitions and seem to be driven by changes of tax rates rather than changes of tax base.
To the best of my knowledge, there has yet to be a theoretical model which explains why austerities can increase output when debt levels are high. Sutherland(1997) only provides an explanation for an increase in consumption following austerities, which works through intertemporal allocation of consumption given an output endowment. A general equilibrium model delivering the EFC result for output will help interpret my empirical results better, and this extension is planned for future research.

APPENDICES

APPENDIX A

The Information Content of Capital Controls

A. Additional tables

Table A1: Capital control and related prudential measures in Brazil, 2006 - 2013

Measure	Announcement date	Source(s)
Limit on banks' foreign exchange exposure was increased to 60% (from 30%)	12/05/2006	F
Bank's capital requirement on forex exposure increased from 50% to 100%	06/11/2007	F
Introduced IOF of 1.5% on fixed income	03/12/2008	F,J
Reduced IOF on fixed income to 0%	10/23/2008	F,J
Introduced IOF of 2% on fixed income and equities	10/20/2009	F,J,CG
Introduced 1.5% tax when foreigners convert ADRs into receipts for local shares	11/18/2009	F,CG
Increased IOF to 4% on fixed income	10/04/2010	F,J,CG
Increased IOF to 6% on fixed income	10/18/2010	F,J,CG
Introduced tax on the cancellation of Depository receipts	12/30/2010	F,CG
Reducing IOF from 6% to 4%	01/03/2011	J
Introduced 60% URR on banks' short FX position > 3bn USD in the spot market	01/06/2011	F,CG
Introduced 2% tax on local corporate offshore borrowing and a 6% IOF on FX loans greater than one year	03/28/2011	F,CG

F: Forbes et al.(2016). CG: Chamon and Garcia(2014). J: Jinjarak et al.(2012)

Table A2: Capital control and related prudential measures in Brazil, 2006 - 2013, continued

Measure	Announcement date	Source(s)
Extended the IOF on FX loans to over two years	04/06/2011	F,CG
Introduced 60% URR on banks' short FX position > 1bn USD in the spot market	07/08/2011	F,CG
Introduced 1% tax on notional amount of currency derivatives	07/26/2011	F,CG
Reduced IOF on equities to 0%	12/01/2011	F,CG
Tax on borrowing abroad extended to maturity below 3 years	02/29/2012	CG
Tighten restrictions on anticipation of exporter payments for up to 1 year	03/01/2012	F,CG
Tax on borrowing abroad extended to maturity below 5 years	03/09/2012	CG
Tax on derivatives for hedging by exporters set to 0%	03/15/2012	CG
Tax on borrowing abroad restricted to maturity below 2 years	06/14/2012	CG
Anticipation of payments to exporters can be done by financial institutions	06/28/2012	CG
Anticipation of payments to exporters allowed between 1-5 years	12/04/2012	CG
Tax on borrowing abroad restricted to maturity below 1 years	12/05/2012	CG
URR on bank's gross FX position applies only after USD 3 billion	12/18/2012	CG
Reduced IOF on fixed income to 0%	06/04/2013	F,CG
Tax on notional amount of derivatives eliminated	06/12/2013	CG

F: Forbes et al.(2016). CG: Chamon and Garcia(2014). J: Jinjarak et al.(2012)

Table A3: Brazil: calendar of data releases within the month

Block name	Series	Timing	Publishing lag
Labor	Employment	20th month	20 days
Trade	Exports	first days	2 days
Trade	Imports	first days	2 days
Capital control	Capital control policy dummy	same day	current month
Industrial Production	Industrial Production: total	first days	one month
Industrial Production	Industrial Production: Consumer goods	first days	one month
Industrial Production	Industrial Production: Capital goods	first days	one month
Industrial Production	Industrial Production: Intermediate goods	first days	one month
Industrial Production	Capacity utilization	first weeks	one month
Survey	Consumer confidence	last week	current month
GDP/Income	Monthly GDP	end	one month
GDP/Income	Retail sales volume	middle	1-2 month
GDP/Income	Amplified retail sales volume	middle	1-2 month
Monetary/Credit	M1	last week	1-2 month
Monetary/Credit	M2	last week	1-2 month
Monetary/Credit	M3	last week	1-2 month
Monetary/Credit	Monetary Base	last week	1-2 month
Monetary/Credit	Total bank reserve	last week	1-2 month
Monetary/Credit	Total loans	last week	1-2 month
Financial/Interest rate	Effective exchange rate index	last day of month	current month
Financial/Interest rate	USD/REAL spot rate	last day of month	current month
Financial/Interest rate	IMF Brazil share price index	last day of month	current month
Financial/Interest rate	OECD Brazil share price index	last day of month	current month
Financial/Interest rate	Brazil central bank Selic policy rate	last day of month	current month
Government Finance	Central Government Budget Balance	last day of month	one month
Government Finance	Primary Balance	last day of month	one month
Government Finance	Net debt % of GDP	last day of month	one month

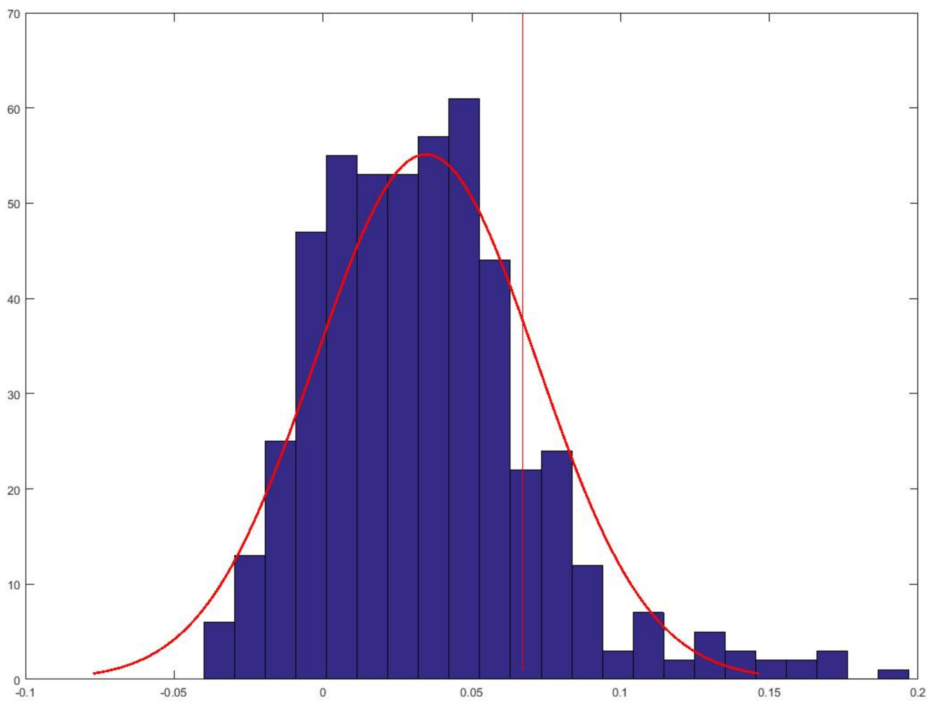
Table A4: Brazil: MSFE of nowcast after a block has been included

Block name	MSFE:1st month	MSFE:2nd month	MSFE:3rd month
Labor and trade	0.6034	0.6495	0.7078
Capital control dummy	0.5479	0.6038	0.6406
Industrial production	0.2791	0.3664	0.4562
Survey	0.2712	0.3676	0.4718
GDP/Income	0.1707	0.2326	0.3606
Monetary/Credit	0.1374	0.1057	0.091
Financial/interest rate	0.1307	0.0946	0.0779
Government finance	0.1366	0.1001	0.0809

MSFE reported here are normalized by the variance of GDP growth during the sample period.

B. Additional figures

Figure A1: Compare MSFE reduction of capital control and of random dummies



C. Computational Appendix

The Matlab code is an extension of the programs used in Bianchi, Liu and Mendoza(2016). The code named "Modelupdate.m" solves the model and is divided into five sections.

Section 1. Parameter Values set the parameter values shown in Table 3. We use 100 points in the grid for bonds, three states for y_T shocks, three states for news shocks, four states for observable tax rates, two states for the random component of the tax rule last period and two states for interest rate shocks. In the decentralized equilibrium, there is no tax imposed and none observed, so the number of states is 18, as in the original paper. In the equilibrium with tax rule and Bayesian updating, the number of states is $18 \times 8 = 144$. The convergence tolerance level for the solution of decision rules is set to $\epsilon = 1e^{-5}$.

Section 2. Construction of Markov Chain discretizes y_T shocks and v_t shocks using Tauchen and Hussey's method. News shocks are incorporated as in the original paper(briefly described on page 17 in section 4.3). Agent's Bayesian updating after observing a capital control tax is incorporated according to formulas in page 18 and 19 in section 4.3 of the paper. On top of y_T, s_t, τ_t and v_{t-1}, I add global liquidity shocks to construct the entire transition probability matrix, assuming independence between y_T shocks, interest rate shocks and v_t shocks.

Section 3. Decentralized equilibrium solves the decentralized equilibrium using the time iteration method described. The solution method is described in detail in Appendix A of Bianchi, Liu and Mendoza(2016). For the state vector $z = (y_t^T, s_t, R_t)'$, the algorithm solves for the recursive functions $c^T(b,z)$, $p^N(b,z)$ and $B(b,z)$ such that the following four conditions are satisfied.

$$p^N(b,z) = (\frac{1-\omega}{\omega})(\frac{c^T(b,z)}{c_t^N})^{\eta+1} \tag{A.1}$$

$$u_T(c^T(b,z), y^N) \geq \beta R(z) E_z[u_T(c^T(B(b,z),z'), y^N)] \tag{A.2}$$

$$B(b,z) \geq -(\kappa^N p^N(b,z) y^N + \kappa^T y^T(z) \tag{A.3}$$

$$B(b,z) + c^T(b,z) = b(1+R(z)) + y^T(z) \tag{A.4}$$

Section 4. Equilibrium with tax rule and Bayesian updating solves the equilibrium when a tax rule is imposed by a macroprudential regulator(as in section 4.2 in this paper) and agent completes a Bayesian updating(as in section 4.3 in this paper) using the time iteration method described. I avoid calling this the social planner's equilibrium because the regulator is not imposing an optimal tax. The solution method is identical to the last section. For the state vector $z_t = (y_t^T, s_t, R_t, \tau_t, v_{t-1})'$, the algorithm solves for the recursive functions $c^T(b,z)$, $p^N(b,z)$ and $B(b,z)$ such that equations 54, 56 and 57 and the following replacement for equation 55 are satisfied.

$$u_T(c^T(b,z), y^N) \geq \beta R(z)(1+\tau_t) E_z[u_T(c^T(B(b,z),z'), y^N)] \tag{A.5}$$

Section 5. Welfare Calculation takes the optimal policy functions derived from section 3 and section 4 of the code, and iterates until convergence to get value functions of the private agent in the decentralized economy and in the economy with tax and updating. Welfare gains are then calculated as in Bianchi(2011). Since the two economies have different state space, I compare, for each of the 8 different combinations of τ_t and v_{t-1}, the value function in the second economy against the value function in the first economy.

The Matlab code "Simulation.m" simulates the model and is divided into two sections.

Section 1. Simulation simulates the model for 201,000 periods. The first 1,000 periods are discarded to eliminate initial condition dependence. The initial bond position is set as mid point of the bond grid for both economies.

Section 2. Event analysis identifies sudden stop events, and finds the surrounding three periods before and after the event. Crisis is defined as 1) current account goes beyond two standard deviation of the ergodic distribution of debt in decentralized equilibrium and 2) collateral constraint binds. The crisis moments are obtained by taking average across all crisis episodes.

D. Difference in margin requirements for tradable and nontradable endowments

One may reasonably anticipate that the foreign lender will require different margins for tradable and nontradable endowments since nontradables cannot be seized in the case of default. In this section of the appendix, we propose a simple environment where the margin requirement for nontradables is lower than that for tradables due to costs related to letigation, transaction and bargaining in the case of default.

The timing of the model goes as follows: in the first period, foreign lender decides on the margin requirements, κ_T and κ_N, fractions of the domestic economy's tradable and nontradable endowments able to serve as collateral in international lending. In the second period, tradable and nontradable endowments are realized and domestic borrower decide whether to default on her debt obligations towards the foreigner. Should default happens, the foreign lender goes to court and pays a legal fee which is fixed a fraction c of the value of collaterals and seize tradable endowments. However, nontradables cannot be seized by the foreigner and shipped abroad, so the foreign lender may sell the legal claims of the nontradables to other domestic agents, who will pay a verification cost γ; Alternatively, the foreign lender may resell these nontradables to the domestic borrower. In the second period, the lender and the borrower may engage in bargaining at the time of legal action and at the time of reselling nontradables.

We solve the model by backward induction. In the final stage of the second period, if the foreign lender decides to sell the legal claims to other domestic agents, she gets $(1-\gamma)p^N Y^N$ after verification. Knowing this, the lender and the original domestic borrower engages in Nash bargaining over the nontradables, where the lender's bargaining weight is $\overline{\pi}$. The lender's value v_N maximizes the following bargaining objective:

$$(v_N - (1-\gamma)p^N y^N)^{\overline{\pi}}(p^N y^N - v_N)^{1-\overline{\pi}} \tag{A.6}$$

First order condition yields $v_N = (1-(1-\overline{\pi})\gamma)p^N y^N$.

Before the borrower decides to default and the lender goes to court, both sides also engages in Nash bargaining, taking into account litigation costs, $c(y^T + p^N y^N)$, and what would happen to nontradable endowments in the case of default. In this bargaining problem, the lender's bargaining weight is π and her value v maximizes the following bargaining objective:

$$(v - y_T + (1-(1-\overline{\pi})\gamma)p^N y^N + c(y^T + p^N y^N))^{\pi}(y_T + (1-(1-\overline{\pi})\gamma)p^N y^N - v)^{1-\pi} \quad \text{(A.7)}$$

First order condition yields $v = [1-(1-\pi)c]y_T + [1-(1-\pi)c-(1-\overline{\pi})\gamma]$.

Anticipating this in the first period, the foreign lender will set $\kappa_T = 1-(1-\pi)c$ and $\kappa_N = 1-(1-\pi)c-(1-\overline{\pi}\gamma)$ respectively. Notice that the foreign lender lends against a smaller fraction of nontradables than tradables because she cannot take nontradable endowments out of the country and has to resell the legal claims on them to either the domestic borrower, with whom the lender bargains, or other domestic agents, in which case a cost of verification occurs.

APPENDIX B

Capital Controls and Signaling: the Case of Self-fulfilling Crisis and Multiple Equilibria

A. Additional tables

Table B1: Iceland: calendar of data releases within the month

Block name	Series	Timing	Publishing lag
Labor	Unemployment	last week	1 month
Trade	Exports: value goods	last week	1 month
Trade	Imports: value goods	last week	1 month
Capital control	Policy stance variable	same day	current month
Survey	Consumer confidence	first week	one week
Production/Sales	Light commercial vehicle sales	mid-month	one month
Production/Sales	Production in total manufacturing	mid-month	one month
Production/Sales	Production in total construction	mid-month	one month
Monetary	M1	22nd	one month
Monetary	M2	22nd	one month
Financial	Real effective exchange rate	last day of month	current month
Financial	Government bond yield: 2-9 years	last day of month	current month

Table B2: Iceland: MSFE of nowcast after a block has been included

Block name	MSFE:1st month	MSFE:2nd month	MSFE:3rd month
Labor and trade	0.7605	0.7613	0.7421
Capital control dummy	0.6862	0.7558	0.7153
Survey	0.6851	0.6914	0.6994
Production/sales	0.5931	0.6365	0.6564
Monetary	0.5785	0.6155	0.6254
Financial	0.5704	0.6105	0.6296

MSFE reported here are normalized by the variance of GDP growth during the sample period.

B. Textual sources on Iceland's capital controls

1. On November 17th 2008, the Iceland PM's office announced "the Central Bank is willing to temporarily maintain restrictions on capital account transactions. Such restrictions have considerable adverse implications and the intention is to remove them as soon as possible."

The followings are excerpts from IMF's AREAER(2009) regarding the content of the control measures which were effective starting November 28th 2008:
1) "Forward contracts and swaps involving the Icelandic krna between residents and nonresidents are not allowed."
2) "The exportation of foreign currency exceeding ISK 500,000 a person a month is prohibited."
3) "Domestic currency accounts are not convertible for capital transactions with securities, unit share certificates in UCITS and investment funds, money market instruments, and other transferable financial instruments."
4) "The debiting of accounts is subject to the requirement that the resident/nonresident demonstrate that the funds will be used in accordance with the foreign exchange rules. It is prohibited to withdraw foreign currency in cash from an FCA without demonstrating that the funds will be used to pay for goods or services, including travel."
5) "Proceeds from the sale of securities, unit share certificates in UCITS and investment funds, money market instruments, and other transferable financial instruments by nonresidents to residents must be credited to domestic currency accounts of the nonresident."
6) "withdrawals from domestic currency accounts for capital transactions, including transfer abroad, except for FDI are not permitted."
7) "residents are required to repatriate to an AD all foreign currency acquired abroad within two weeks of the date the foreign currency was or could have been acquired. If the person cannot repatriate the foreign currency, an explanation must be given to the AD. Repatriated foreign currency must be sold or deposited to an FCA account with an AD."
8) "The purchase of shares for foreign currency is not permitted except for reinvestment of investments made prior to that date. The proceeds must be reinvested in the same type of instrument within two weeks."
9) "The issuance and sale of securities denominated in foreign currency are prohibited if the settlement takes place in Icelandic krnur. If the issuance is denominated in Icelandic krnur, the proceeds from the sale must be deposited to a krna-denominated account, in the issuers name, in an AD in Iceland. Krna-denominated financial instruments may not be settled in foreign currency, and the proceeds must be deposited to the nonresidents account with an Icelandic AD."
10) "Derivatives contracts involving the Icelandic krna against a foreign currency are not allowed except for derivatives transactions related solely to trade with goods and services."
11) "Lending to/borrowing from nonresidents is allowed only for loans with a maturity of at least one year and in an amount not exceeding ISK 10 million a person a calendar year. Loan agreements must be submitted to the AD involved in the transactions within one week of signing. Lending between undertakings within a group is freely permitted. Prepayment of loans is not allowed."

2. The IMF AREAER notes that effective April 1st 2009, "domestic currency may not be used for payments for export transactions. Exporters were required to invoice and collect payments for exports in convertible foreign currency."

3. The IMF AREAER notes two announcements of opposite directions on September 11th 2011: 1) "residents must repatriate with an AD all foreign currency acquired abroad within three weeks (previously, two weeks) of the date the foreign currency was or could have been acquired. Repatriated foreign currency must be sold or deposited in a foreign exchange account with an AD. Exporters must invoice and collect payments for exports in convertible currency. ADs are exempt from the repatriation requirement", and 2) "residents may buy foreign exchange, up to ISK 100 million to purchase real estate abroad for resettlement. Previously, there was no limit on the amount used for real estate purchase related to resettlement."

4. The IMF AREAER notes two announcements of further tightening on March 13th 2012: 1) "Act No. 17/2012 rescinds the exemption (1) for payments from bankruptcy and payments of contractual claims in accordance with the composition of creditors agreements in domestic currency when payment is disbursed from the payers account with a financial institution in Iceland; (2) from the prohibition on cross-border movement of foreign currency, which previously applied to bank resolution and windingup committees." 2) "prohibited the purchase of foreign currency for the payment of bond principal and indexation on bond principal."

5. The IMF AREAER notes that effective March 9st 2013, "according to changes to Foreign Exchange Act No. 87/1992, CBI exemptions concerning a financial undertaking or legal entity of which the Financial Supervisory Authority has taken control by appointing a resolution committee or provisional board of directors, or a legal entity for which a winding-up board has been appointed in accordance with Act No. 161/2002, and if the exemption involves an authorization for foreign currency trading and cross-boarder capital movements of more than ISK 25 billion annually, will be granted only after consultation with the minister of finance and economic affairs and the minister responsible for financial market affairs, following a presentation by the minister to the Economic and Trade Committee of the Althingi(parliament) on their economic impact."

6. The IMF AREAER notes several announcements on April 3rd 2013, most of which are loosening of controls:
1) "Residents may not transfer foreign currency from Iceland for deposit abroad, but the deadline for residents to deposit foreign exchange proceeds from their investments abroad was increased to six months (previously two weeks) before repatriation or investment in similar investments abroad, if they invested in such financial instruments before November 28, 2008."
2) "With Central Bank of Iceland permission, residents may buy up to ISK 10 million in foreign currency to purchase and import one vehicle from abroad a calendar year provided the vehicle is intended for personal use domestically."
3) "Limits on transfers relating to living expenses were raised. Nonresidents may now transfer abroad up to the equivalent of ISK 6 million (previously ISK 3 million) a calendar year from these accounts for living expensesISK 12 million (previously ISK 6 million) for married couples and cohabiting partners and ISK 4 million (previously ISK 2 million) for each minor child in their custody who lives with them."
4) "Use of krna balances for investment in financial instruments issued in domestic currency, previously limited to real estate and securities eligible as collateral for Central Bank of Iceland (CBI) facilities, is now limited to instruments on CBI exemption lists, and the proceeds that are not convertible krna-denominated financial investments from vostro accounts previously limited to securities eligible as collateral for CBI fa-

cilities are now limited to financial instruments issued in domestic currency that are on the CBI exemption list."
5) "Dividend payments exceeding ISK 1 million and interest/indexation/contractual payments exceeding ISK 10 million now require Central Bank of Iceland permission."
6) "Cross-border capital movements in connection with imports of foreign currency to a deposit account with a domestic financial institution are allowed. Other capital transactions, in particular those in krnur, are prohibited."
7) "The purchase of securities abroad requires Central Bank of Iceland permission, except for reinvestment within six months (previously two weeks) of proceeds from such investments made before November 28, 2008."
8) "Krna-denominated investments from vostro accounts are limited to securities on the Central Bank of Iceland (CBI) exemption list (previously securities eligible as collateral for CBI facilities). Foreign exchange may not be purchased for the payment of bond principal and indexation on bond principal.

7. On June 8th 2015, the Central Bank of Iceland(CBI) notes that "Announcement by PM concerning capital account liberalisation measures: proposal of a comprehensive action plan for removal of capital controls along with a stability tax to ensure that the final winding-up of the failed bank's estates does not jeopardise monetary, exchange rate, and financial stability. The estates will have until the year-end to obtain an exemption from the Foreign Exchange Act guaranteeing that the relevant conditions are fulfilled."

8. On October 28th 2015, the CBI notes that "the draft composition agreements submitted by the estates of the three failed banks satisfy the requirements set forth in the Foreign Exchange Act, in that the implementation of the composition agreements together with the proposed mitigating measures will not jeopardise monetary, exchange rate, or financial stability."

9. On May 25th 2016, the CBI notes that "a foreign currency auction would be held on 16 June 2016, in which the Central Bank of Iceland offers to purchase krnur in exchange for cash payment in foreign currency.More specifically, the Bank offers to buy krnur defined as offshore krnur according to Act no. 37/2016."

10. On October 21th 2016, the CBI notes that "Law amending the Foreign Exchange Act, no. 87/1992 took effect on 21 October 2016. Their purpose is to lift capital controls on households and businesses. The new legislation became effective on 21 October. The principal changes made with the amending Act entail increased authorisations for foreign exchange transactions and cross-border movement of capital, plus the removal of specific restrictions that have applied to foreign exchange transactions and cross-border movement of capital."

11. On March 12th 2017, the removal of the last remnants of Icelandic capital controls received international media coverage by The Economist and New York Times, among others. It is reported that "The last remaining controls on capital outflows were lifted, allowing pension and investment funds to invest their money abroad", and that "the central bank struck another deal with offshore holders of frozen krona-denominated assetsbuying more of them back at a discount."

APPENDIX C

Expansionary Fiscal Austerity: new International Evidence

A. Description of algorithm for panel PVAR

1. Import data for all countries and transform data appropriately to ensure stationarity.
2. For each country, estimate the first step by an OLS estimator as in equation 1. Save residuals $u_{i,t}$.
3. Estimate structural parameters of the panel proxy SVAR using $u_{i,t}$s in the second step and $m_{i,t}$s as input, imposing identification restrictions in Mertens and Ravn(2013).
4. Compute impulse responses functions for each country using country-specific reduced form parameters $\Omega_i^d = [A_{0,i}, A_{1,i}, ..., A_{p,i}]$ and common structural parameters in the matrix B.
5. Compute average impulse response function. Compute the confidence intervals of the average IRF using a wild bootstrap procedure designed specifically for our setting.

B. Computational Appendix

In this section, I describe the algorithm used to compute bootstrap confidence intervals of our average impulse response function. These CIs can be though of as an average of the bootstrap CIs for each individual country. The methodology extends Mertens and Ravn(2013) to a panel setting where I pool estimates of structural parameters.

a) Bootstrap iteration j

1) Loop over country i

i. Create random vector v_i of length $T_i \times 1$, which takes values 0.5 or -0.5 with probability each (T_i is number of time observations in country i)

ii. Create new residual vector $u_i = u_i \times v_i$

iii. Create new dependent variable vector $Y_i = A_i \times X_i + u_i$, where $A_i \times X_i$ is the VAR model estimated in the first step for country i

2) Assemble new dependent variable Y by combining the country-specific vectors Y_i

3) Run model with new dependent variable Y and original proxies M

i. Estimate VAR, country by country (1st step)

ii. Narrative identification, pooling across countries (2nd step)

iii. Compute average IRF

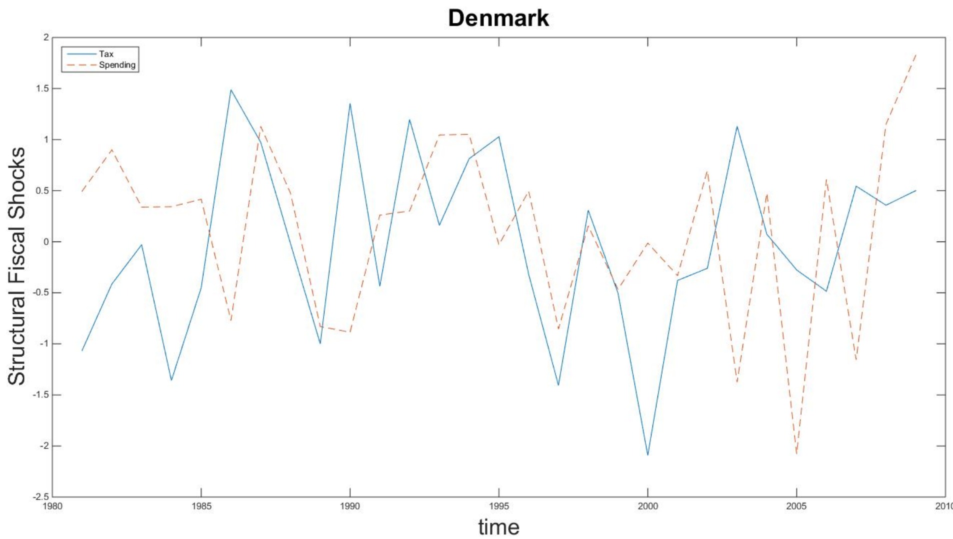
4) Store IRF of iteration j

b) Run for B iterations

c) Get the 5th and 95th percentiles of the IRF distribution

C. Additional figures

Figure C1: Exogenous changes in tax and spending in Denmark



D. Additional tables

Table C1: Calibration of the Sutherland Model for OECD Countries

	Parameter(%)					
	r	θ	T	σ	U	L
AUS	9.2	1.28	2.47	2.07	80	-80
AUT	5.57	1.3	2.49	1.26	60	-60
BEL	7.44	1.3	7.46	3.59	60	-60
CAN	7.88	1.28	7.92	3.17	80	-80
DNK	6.53	1.31	6.69	3.14	80	-80
FIN	6.9	1.3	11.43	3.48	60	-60
FRA	7.84	1.29	1.12	1.36	60	-60
DEU	6.14	1.3	3.68	1.82	60	-60
IRE	8.42	1.31	7.39	4.44	60	-60
ITA	6.58	1.28	11.98	3.33	60	-60
JPN	2.81	1.25	1.98	3.47	80	-80
NLD	6.4	1.29	5.64	2.11	60	-60
PRT	5.69	1.33	3.53	2.24	60	-60
ESP	9.42	1.28	5.44	2.98	60	-60
SWE	7.14	1.27	5.75	4.67	80	-80
GBR	8.06	1.3	2.54	3.22	80	-80
USA	7.24	1.32	1.84	2.54	80	-80

This table gives numerical values of parameters I used to calculate B^*, the debt level that defines the regime dummies in section 5.

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