



THE WILLIAM DAVIDSON INSTITUTE
AT THE UNIVERSITY OF MICHIGAN BUSINESS SCHOOL

Start-Ups and Transition

by Daniel M. Berkowitz and David J. Cooper

Working Paper Number 84
September 1997

The Davidson Institute Working Paper Series

The Davidson Institute
701 Tappan Street
Ann Arbor, MI 48109-1234 USA
Tel. (734) 763-5020
Fax (734) 763-5850
wdi@umich.edu
<http://www.wdi.bus.umich.edu>

Copyright Daniel M. Berkowitz and David J. Cooper, 1997. Disseminated by the Davidson Institute with permission of the authors.

Start-ups and Transition*

Daniel M. Berkowitz
Department of Economics
University of Pittsburgh
Pittsburgh, PA 15260
telephone: (412) 648-7072
e-mail: dumberk+@pitt.edu

David J. Cooper
Department of Economics
University of Pittsburgh
Pittsburgh, PA 15260
telephone: (412) 648-1748
e-mail: dcooper@vms.cis.pitt.edu

September 1997

* This is a substantially revised version of our paper entitled, "Initial Conditions and Efficiency in Transition Economies". We would like to thank Dan Friedman, Esther Gal-Or, Phil Reny, Al Roth, and Jan Svejnar for their helpful comments. We have also benefitted from the comments of participants in the workshop "Economic Transformation - Institutional Change, Property Rights and Corruption" organized by the National Research Council's Task Force on Economies in Transition and participants at the economics seminar at the Fuqua School of Duke University. We would like to thank Mary Gromicko for her help in preparing this text. Our research was partially supported by Faculty Research Grants from the Faculty of Arts and Sciences, University of Pittsburgh. Berkowitz conducted part of this research during his appointment as a Research Fellow at the University Center for International Studies, the University of Pittsburgh.

Abstract

Start-ups and Transition

Daniel M. Berkowitz and David J. Cooper
Department of Economics
University of Pittsburgh
Pittsburgh, PA 15260

September 1997

Abstract

How fast transition should occur and how fast privatization and/or entry should take place in formerly socialist economies has been widely debated by economists. The field evidence on start-ups is mixed, with fragmentary data indicating that the performance of start-ups varies widely across countries. The evidence suggests that two vastly different equilibria are emerging in transition economies: a high development equilibrium and a low development equilibrium. In the high development equilibrium start-ups supply higher quality goods than transforming SOEs, aggregate supplies are ample and start-ups are a growth engine. This contrasts with the low development equilibrium in which start-ups provide lower quality goods and the overall supply of goods is lower.

In this paper, we develop a dynamic model which explains how features of the transition can push an economy to either the high or low development equilibrium in the long run. We concentrate on the speed with which bureaucratic interference in the economy is eliminated and the speed with which entry by private firms occurs. Our central conclusion is that delayed entry by start-ups can substantially increase the likelihood of the high development outcome, especially when bureaucratic interference is persistent. Our result captures how this interference, while transitory, can have a negative long run impact and underlines the importance of government policies to encourage entrepreneurship, such as subsidies and tax breaks.

Key Words: Adaptive learning, transition.

1. Introduction

During the transition to a market economy in the former Soviet Union and Eastern Europe, there has been a rapid entry of new firms. These firms tend to be small or medium sized enterprises; most are start-ups and are created *de novo*, while a substantial number of these firms are spin-offs of former state owned enterprises (SOEs).¹ Start-ups compete with privatized and restructured SOEs in retail, trade and construction services and, in the most advanced transition economies, in manufacturing. Without question, start-ups will play an important role in determining the future success of transition economies.

How fast transition should occur and how fast privatization and/or entry should take place has been widely debated by economists. Differing opinions abound. Kornai (1990) argues that the rapid entry of start-ups is more important than reform of state enterprises. Blanchard and Kremer (1997, forthcoming) suggest that a rapid entry of start-ups (captured by an improvement of production possibilities outside the transforming state sector) reduces the output fall associated with transition. In contrast, Aghion, Blanchard and Burgess (1994) conclude that a slow privatization encourages start-ups which come from the state sector to restructure pre-privatization. Murrell and Wang (1993) propose that privatization of SOEs which would become start-ups should be delayed so that scarce investment resources are available for *de novos*, which tend to be more efficient suppliers. Taking a middle course, Friedman and Johnson (1995) argue that the optimal intensity with which start-ups enter depends upon the economy's potential for creating these firms. Thus, entry is more intense the lower are start-ups' costs and the greater was start-ups' market share under socialism.

The field evidence on start-ups is also mixed, with fragmentary data suggesting that the performance of start-ups varies widely across countries. In some locations, start-ups have made important contributions to the transition. Berg (1994), Cannon (1995) and Johnson and Loveman (1995) observe that start-ups in Poland provide relatively high quality consumer goods and services and argue that these start-ups are an important engine

¹For the rest of the paper, start-ups include *de novo* firms as well as spin-offs which now operate outside the state distribution and incentive system. This distinction is made by Johnson and Loveman (1995) for Poland.

of growth in the buoyant Polish economy. Small and medium sized manufacturing enterprises are perhaps one of the most dynamic sectors in the successful Czech economy (Zemplerova' and Stibal (1995)). This sector is comprised largely of start-ups and spinoffs as well as firms from former SOEs and firms emanating from restitutions and privatization. Survey evidence in Benacek (1996), Webster (1993a, 1993b) and Webster and Swanson (1993) suggests that start-ups in the Czech Republic, Hungary, Poland and Slovakia are supplying high quality goods that were either difficult to obtain or unavailable before transition.

Start-ups have had a less positive effect in other locales. Consumers and politicians have complained about the performance of new firms. Many start-ups tend to be small "fly-by-night" operations, taking advantage of shortages by charging high prices for low quality goods. In the early 90s, footwear and clothing supplied by non-state and private firms in the former Soviet Union was notorious for its poor quality and limited supplies (Shelley (1992)). In the languishing economies of Belarus, Kyrgyzstan and Tajikistan start-ups have tiny market shares and there is no evidence that they supply high quality goods in consumer and manufacturing markets (EBRD (1995), chpt 9).

The field evidence suggests that two vastly different equilibria are emerging in transition economies: a high development equilibrium and a low development equilibrium. In the high development equilibrium start-ups supply higher quality goods than transforming SOEs, aggregate supplies are ample and start-ups are a growth engine. This contrasts with the low development equilibrium in which start-ups provide lower quality goods and the overall supply of goods is lower.

In this paper, we develop a dynamic model which explains how features of the transition can push an economy to either the high or low development equilibrium in the long run. Unlike the existing literature, we allow the quality and cost of goods produced by start-ups to be determined endogenously. We concentrate on the speed with which bureaucratic interference in the economy is eliminated and the speed with which entry by private firms occurs. Our central conclusion is that delayed entry by start-ups can substantially increase the likelihood of the high development outcome, especially when bureaucratic interference is persistent. Our result

captures how this interference, while transitory, can have a negative long run impact and underlines the importance of government policies to encourage entrepreneurship, such as subsidies and tax breaks.

The model begins with an early transition phase in which price controls are no longer in effect and the SOE operates as a monopolist choosing output quantity and quality. Government interference (e.g. employment requirements, soft budget constraints, or output subsidies) artificially lowers the SOE's costs and, therefore, distorts the SOE's choices of output quantity and quality. Next follows a mid-transition phase in which the SOE faces lessening government protection and its costs begin to rise. At some point during this phase, a start-up enters the market and competes with the SOE in quality and quantity. While the start-up has inherently lower costs than the SOE, it faces temporary discrimination in input and credit markets, which artificially raises its costs.² As transition progresses, input and credit markets gradually develop and the share of inputs and credits that are allocated by bureaucrats diminishes. This is reflected in falling unit costs for the start-up and increasing unit costs for the SOE. The late transition phase starts when government interference in the input and credit market ceases and the start-up and SOE have equal access. Eventually, the economy converges to one of two possible steady state outcomes, corresponding to the high or low development equilibrium.

The dynamics of firms' choices during transition are driven by an adaptive learning process similar to fictitious play. Each firm forms beliefs about its opponent's strategy using observations of past outcomes, and gradually learns to optimize given its beliefs. In using this methodology, we draw upon recent developments in game theory. As game theorists have become increasingly disenchanted with the strong rationality assumptions underpinning standard equilibrium concepts, attention has turned to models in which agents are boundedly rational, adopting strategies via an adaptive process rather than a deductive process. Theorists and experimenters

²State bureaucrats who have been historically hostile to private enterprise have substantial control over input and credit markets during transition, putting start-ups at a disadvantage (Kornai, 1992, chapter 19). In a survey of Russian industries in 1995, Earle and Rose (1996) find that there is much more local government interference with start-ups than former SOEs.

have achieved notable results using the adaptive learning approach, but little attention has been focused on applied problems.³

The adaptive learning approach captures the lack of information and experience facing both transformed SOEs and start-ups during the transition. With few exceptions, private market activity under socialism was highly constrained and private market share was insignificant. New entrepreneurs as well as the managers of restructured and privatized SOEs had little experience with operating in a competitive environment. Start-ups entered markets in a chaotic period of rapid structural change. New firms were entering industries, old firms were operating under new incentive schemes, and laws and institutions were rapidly changing. Even the most basic sources of information such as telephone books and transportation schedules were often lacking (Sheppard (1994)). In this environment, we conjecture that inexperienced managers of start-ups and former SOEs would have few guides to their opponents' likely current behavior beyond their opponent's past behavior.

In keeping with this, the early transition phase of our model forms the basis for initial beliefs following entry. In our dynamic model, managers do two types of learning: learning to maximize profits and learning the other firm's quantity and quality. During the early transition phase, the learning problem faced by the former SOE is simple. With no opponent, it only needs to learn how to maximize profits. Using a process of trial and error, the SOE moves rapidly toward its optimal quantity and quality levels.

Learning becomes more difficult once entry occurs. Not only must each firm learn to optimize, it must also learn about its opponent's strategy. At the time of entry, the start-up's best guess about how the former SOE will behave is based on the SOE's choices during the early transition phase. Subject to its beliefs, the start-up learns to optimize via a process of trial and error. The start-up is boundedly rational and has limited time and energy to consider all possible strategies. Therefore, in each period it compares expected profits from its past

³For a summary of the extensive theoretical literature on learning, see Fudenberg and Levine (1996). Experimental support for the adaptive learning approach has also come from many sources, including Crawford (1995), Partow and Schotter (1993), Cooper, Garvin, and Kagel (1994a and 1994b), Roth and Erev (1995), Gale, Binmore, and Samuelson (1995), and Brandts and Holt (1994). For other examples of applied work using models of adaptive learning see Friedman and Fung (1994), Lagunoff (1995), and Glaeser, Sacerdote, and Scheinkman (1996).

strategy with expected profits, subject to its beliefs about the SOE's quantity and quality levels, from a random sample of strategies. The start-up chooses the strategy from its sample which maximizes its expected profits. It then observes the SOE's actual strategy. Using this observation, the start-up updates its beliefs about how the former SOE will behave in the next period. The updating process adds weight to the former SOE's current strategy and reduces the start-up's expectations that all other strategies will be chosen. The SOE learns how to compete versus the start-up in an analogous fashion. Over time, this adaptive learning process converges to a steady state in which each firm's beliefs correctly predict the other's actions and each firm maximizes its profits subject to its beliefs. Depending on the path of play, this steady state can correspond to either the high or low development equilibrium.

We analyze our dynamic model of transition via simulations. Four parameters of the model are randomly selected for each simulation: length of the early transition phase, the extent of initial cost discrimination against the start-ups, length of the mid-transition phase, and time of entry. Statistically analyzing the simulation output, we make three strong predictions about the relationship between these parameters and the probability of the high development equilibrium. First, decreasing the initial cost discrimination against the entrant makes the high development equilibrium more likely. Second, the shorter the duration of the mid-transition phase, the more likely the high development equilibrium is to occur. Finally, delaying the time of entry makes the high development equilibrium more likely. Rather than calling unambiguously for a slow or a fast transitions, our results suggest some parts of transition should be fast while others are slow. More specifically, long run efficiency depends on the rapid reduction and/or elimination of bureaucratic interference in input and credit markets and the operations of existing firms coupled with delayed entry by private firms.⁴

The key insight behind our results is that the initial conditions in which entry takes place play a central role in determining the long run equilibrium because initial behavior forms the basis for long run beliefs. Without

⁴Adjusting the length of the early transition phase has an ambiguous effect. If this phase is relatively short, increasing its length decreases the likelihood of the high development equilibrium. This result reverses when the early transition phase is relatively long.

any distortions, the start-up is the low cost producer. Upon entry, it naturally takes the high quality role. Since it is profitable in our model for any firm to differentiate itself from its opponent, high quality output from the start-up pushes the former SOE to lower quality levels. As players form expectations that the start-up will produce higher quality goods than the SOE, play moves smoothly to the efficient high-development equilibrium. High cost discrimination, slow elimination of cost distortions, and fast entry all have the same effect; because the start-up's costs at the time of entry are artificially high relative to the former SOE's costs, the start-up tends to initially take the low quality role rather than its natural high quality role. Forces of product differentiation then push the SOE to even higher quality levels. Eventually, even though the start-up is the low cost producer in the long run, expectations that the start-up will produce lower quality goods than the former SOE push play to the low development equilibrium. Even though both firms (and consumers) would benefit from a switch in roles, neither believes that the other will actually make a switch. Due to its impact on belief formation, transitory distortion in input markets induces the low development equilibrium in the long run.

Our result on the timing of entry can explain differences in market performance. Currently, the number of start-ups per capita in Russia is much less than in Poland, and there is evidence that start-ups in Russia are not generally supplying the kinds of high quality goods available in Poland (see Aslund (1997)). One explanation for this outcome from our model is that entry began too early in Russia. The laws on cooperatives and private enterprises which opened the door to legally registered small scale enterprises in Russia were implemented in the latter half of the 1980s. These firms entered the market years before price liberalization, privatization and development of input and credit markets. In contrast, Polish input and credit markets were more highly developed and price liberalization was in effect when the burst in start-up entry began.

The importance of creating a level playing field in our model may also explain the success of start-up manufacturing firms in the Czech Republic. Input and credit markets had been tightly controlled under the Communists and at the start of transition start-up firms had higher costs than former SOEs. However, start-ups received subsidies on purchases of inputs and credits from the government (see Zemplerova' and Stibal

(1995)). This compensation offset cost discrimination and may have pushed the Czech manufacturing sector onto a path converging to the efficient outcome.

The rest of the paper is organized as follows. In Section 2, we develop a static model of a market economy in which a start-up and SOE compete and derive conditions under which a high (efficient) and low (inefficient) equilibrium exist in the long run. Section 3 develops a static model of an SOE in the early transition phase. Section 4 introduces the adaptive learning model and the dynamic model of transition. In Section 5, we analyze simulation results based on our dynamic model of transition, demonstrating that speed of transition, time of entry, and cost distortions due to state interference or underdeveloped input and credit markets impact the selection of an equilibrium. Section 6 concludes.

2. Long-run Equilibria

This section develops and characterizes the long-run equilibria for a market in which a start-up (entrant) and a former SOE (incumbent) compete in quality and quantity. We derive conditions under which there exist two long-run equilibria which are Pareto rankable. In the proceeding sections we show how features of the transition can push the market to the Pareto inferior outcome with high probability.⁵

Let there be a continuum of consumers indexed by taste parameter x which is uniformly distributed over the interval $[0, X]$. Each consumer either buys a unit of the good from a firm or withdraws from the market. Each consumer's willingness to pay is

$$U(m, x) = m(a + bx), \quad a, b \geq 0, \quad (1)$$

where m denotes the quality of the good. There are no income effects and a consumer who withdraws from the market earns a payoff of zero. Under this specification, any consumer is willing to pay more for higher quality,

⁵We extend the models of Shaked and Sutton (1982) and Gal-Or (1985) to allow firms to have different cost functions. Their results concerning product differentiation trivially extend to the case of asymmetric costs. For an application of this model to socialist economies, see Berkowitz (1993).

and a high index consumer is willing to pay more for the good than a low index consumer. A consumer x who buys a product of quality m at price p receives a surplus of $U(m,x) - p$.

Firms simultaneously choose product quality and quantity. Unit costs are increasing and convex in quality and have constant returns to scale in quantity. For concreteness, we use the following functions, where e and I denote entrant and incumbent, and the entrant is more efficient than the incumbent:

$$c^I(m^I) = (m^I)^2, \quad c^e(m^e) = \alpha(m^e)^2: \quad \alpha \leq 1. \quad (2)$$

Quality can be interpreted as a composite of many characteristics which determine the desirability of the good. To describe changes in quality associated with transition, we concentrate on two such characteristics: availability and durability. Higher availability implies that a consumer bears lower transactions costs in purchasing a good; higher durability represents an increase in the good's physical quality.

Under socialism, the physical quality of goods was low and there were pervasive shortages (Kornai (1980)). Typically, SOEs could receive higher prices by diverting goods to high valuation consumers who were willing to make side-payments in addition to the posted state price. This represents an increase in quality through an increase in availability -- consumers were paying more for the same physical goods, but gained improved access. During the transition, some start-ups have been accused of selling low quality goods at unreasonably high prices. Once again, such prices represent an increase in quality through availability rather than durability. In market economies, the physical quality of goods is relatively high and goods are typically easily available. Here, price increases are more likely to reflect upgrades in the physical quality or durability of a good than increases in availability. Thus, we would like to model quality in such a way that at low quality levels increases in quality are largely through increases in availability while at high quality levels increases in quality are primarily through increases in durability.

These features can be easily formalized. Let $m = m_a + m_d$, where m_a is the availability of the good and m_d the durability of the good. Suppose the unit cost functions for availability and durability are quadratic:

$c(m_a) = k_1^a m_a + \frac{1}{2} k_2^a m_a^2$ and $c(m_d) = k_1^d m_d + \frac{1}{2} k_2^d m_d^2$. Assume that $k_1^a < k_1^d$ and $k_2^a > k_2^d$. Therefore, marginal costs are lower for availability at low levels of quality and are lower for durability at high levels of quality. For any given level of quality m , the firm chooses availability and durability so as to minimize the unit cost of m : formally, the firm minimizes $c_a(m_a) + c_d(m_d)$ subject to $m_a + m_d = m$. Solving the firm's problem yields $m_a(m) = m$, $m_d(m) = 0$ if $m < (k_1^d - k_1^a) / k_2^a$. In this low quality range, increases in quality are reflected solely as improvements in availability. In the high quality range of $m \geq (k_1^d - k_1^a) / k_2^a$, $m_a(m) = (k_1^d - k_1^a + k_2^d m) / (k_2^a + k_2^d)$ and $m_d(m) = (k_1^a - k_1^d + k_2^a m) / (k_2^a + k_2^d)$; increases in overall quality lead to an increase in durability. As $m \rightarrow \infty$, the majority of overall quality consists of durability.⁶

Each consumer takes prices and qualities as given and maximizes surplus by choosing either to buy a good or to withdraw from the market. Prices are a function of the firms' quantity-quality pairs, and are selected to clear the market. Once quantity-quality pairs have been selected by the firms, one firm's good can be identified as the high quality good and one firm's good can be identified as the low quality good. Let (q_h, m_h) be the quantity-quality pair for the high quality good and (q_L, m_L) be the quantity quality pair for the low quality good. Since most markets in transition economies are not saturated with goods, we restrict our analysis to cases in which $q_L + q_h < X$. Following Gal-Or (1985), prices for the high and low quality goods, p_h and p_L respectively, are given by (3a) and (3b).

$$p_h = m_h[a + b(X - q_h)] - b m_L q_L \quad (3a)$$

$$p_L = m_L[a + b(X - q_h - q_L)] \quad (3b)$$

Given (3a) and (3b), firms' revenues and profits are calculated in the standard fashion.

In the long-run, the industry must be in a Nash Equilibrium. In other words, each firm chooses a profit maximizing quality-quantity pair, given the quantity-quality pair of the other firm. As shown by Shaked and Sutton (1982, p.9) and Gal-Or (1985, p. 313), if both firms have positive market share, then one firm will provide

⁶The derived cost function, $c(m) = c_a(m_a(m)) + c_d(m_d(m))$ is quadratic for $m \geq (k_1^d - k_1^a) / k_2^a$. This follows from the quadratic form of the underlying cost function and is consistent with the quadratic form shown in (2).

strictly higher quality than the other. Thus, there are two possible types of equilibria -- one in which the former SOE (incumbent) produces the higher quality good and one in which the start-up (entrant) produces the higher quality good. In the next two lemmas we compute the two Nash equilibrium outcomes and provide a sufficient and necessary condition for the existence of both equilibria. The proofs for all lemmas in this paper are contained in Appendix A. Superscripts indicate whether quantity/quality is produced by the incumbent SOE (I) or the entering start-up (e).

LEMMA 1. *If $3/2 > \alpha > 2/3$, equations (4a - d) give the unique possible equilibrium outcome when the incumbent produces the strictly higher quality good, and equations (5a - 5d) give the unique possible equilibrium outcome when the entrant produces the strictly higher quality good. Equation (6) ensures that $q_L + q_h < X$ in both equilibria.*

$$q_h^I = \frac{(9 - 4\alpha)(a + bX)}{b(27 - 4\alpha)} \quad (4a)$$

$$q_L^e = \frac{6(a + bX)}{b(27 - 4\alpha)} \quad (4b)$$

$$m_h^I = \frac{9(a + bX)}{\alpha(27 - 4\alpha)} \quad (4c)$$

$$m_L^e = \frac{6(a + bX)}{27 - 4\alpha} \quad (4d)$$

$$q_h^e = \frac{(9\alpha - 4)(a + bX)}{b(27\alpha - 4)} \quad (5a)$$

$$q_L^I = \frac{6\alpha(a + bX)}{b(27\alpha - 4)} \quad (5b)$$

$$m_h^e = \frac{9\alpha(a + bX)}{(27\alpha - 4)} \quad (5c)$$

$$m_L^I = \frac{6(a + bX)}{27\alpha - 4} \quad (5d)$$

$$\frac{27a}{16a + 12bX} < \alpha < \frac{16a + 12bX}{27a}, \quad (6)$$

LEMMA 2. *Both equilibria exist if and only if equation (6) holds and $.829 < \alpha < 1.207$.*

Along with the restriction $\alpha \leq 1$, Lemma 2 implies that both types of equilibrium exist only when the entrant's cost advantage is not too large. If $\alpha \leq .829$, the entrant's cost advantage is so great that it always produces the higher quality product in equilibrium.⁷

If $.829 < \alpha < 1$, the equilibrium which generates both the largest consumer surplus and the largest producer surplus is always the one in which the entrant is the higher quality producer, since by eqs (4a - d) and (5a - d) there is greater product differentiation and higher overall supply when the entrant produces higher quality ($m_h^e > m_h^i$, $m_L^e > m_L^i$, and $q_h^e > q_h^i$, $q_L^e > q_L^i$). Firm level and aggregate profits are compared in the next lemma.

LEMMA 3. *If both equilibria exist and $\alpha < 1$ then*

- i) $\pi_h^e > \pi_L^e$;
- ii) $\pi_h^i > \pi_L^i$: $\alpha \in (.939, 1)$; $\pi_h^i < \pi_L^i$: $\alpha \in (.829, .939)$;
- iii) $\pi_h^e + \pi_L^i > \pi_h^i + \pi_L^e$.

According to lemma 3, the entrant earns the most profits in the equilibrium in which it produces higher quality. When $\alpha \in (.829, .939)$, it is more profitable for the incumbent to service the lower end of the market, and the equilibrium in which the entrant provides high quality Pareto dominates the equilibrium in which the incumbent provides high quality. Thus, the equilibrium in which the entrant (start-up) provides higher quality corresponds to the high development equilibrium while the equilibrium in which the incumbent SOE provides higher quality corresponds to the low development equilibrium.

For all of the simulations reported in this paper, we set $a = 0$, $b = 2$, and $X = 10$. Setting $a = 0$ is a sufficient condition for $q_h + q_L < X$ in equilibrium. The choice of parameters was otherwise arbitrary.

⁷The restriction on α , $.829 < \alpha < 1.207$, is a sufficient and necessary condition for neither firm to be able to deviate profitably from an equilibrium by a discontinuous change in its quantity-quality pair.

Equilibrium strategies, profits, consumer surplus, and total welfare are listed for these parameter values in Table 1, with $\alpha = .9$ and $\alpha = 1.0$. With $\alpha = .9$, the equilibrium in which the entrant produces the high quality good Pareto dominates the equilibrium in which the incumbent produces the high quality good.

(Table 1 here)

In summary, the model developed in this section describes the long run outcome for an industry in transition. Consistent with observed outcomes, there can be either a high development equilibrium or a low development equilibrium. In the following sections we develop a dynamic model of transition which allows us to predict what conditions will lead to the high or low development outcomes.

3. The Early Transition Phase

The dynamic model contains three phases, early, mid, and late transition. As the dynamic reaches its culmination in the late transition phase, it converges to either the low or high development equilibrium, as developed in Section 2. Which equilibrium emerges depends on what has occurred in earlier phases. This history dependence arises in the model because of the firms' bounded rationality; facing the chaotic environment of transition, we postulate that inexperienced managers facing the chaotic environment of transition would rely on their opponent's previous behavior to predict current behavior. Thus distortions in early play caused by details of the transition lead to distortions in later beliefs, affecting which equilibrium emerges.

This section describes the early transition phase in which the former SOE operates as a monopolist, albeit a monopolist subject to substantial outside interference. By itself, the early transition phase is of scant interest. The SOE has very little to do in this phase -- it only needs to learn how to maximize its profits in a static environment, a trivial problem in the absence of strategic uncertainty. However, the SOE's behavior in the early transition phase serves as the foundation for the start-up's beliefs following entry. In this section, we show that state interference with the SOE which lowers unit costs increases the quality levels chosen by the SOE in the early transition phase. This distortion of early transition choices by the SOE affects initial beliefs for the start-up.

Through this linkage, outcomes in the early transition phase play a critical role in determining whether the high or low development equilibrium ultimately emerges.

During early transition, central planning no longer takes place, and output prices are liberalized. However, the government, either national or local, still exercises substantial influence over the former SOE's operations. In terms of market structure, the government erects sufficiently high barriers to entry that the former SOE operates as a monopolist until the mid-transition phase. Other government actions affect the SOE's costs; continued government control of input allocations provides materials to the SOE at subsidized prices, and the SOE continues to operate under a soft budget constraint during early transition, allowing it to obtain cheap credits to pay for inputs and capital goods. While other forms of government interference, such as requirements that the SOE provide health benefits, education, and social services to employees, have negative consequences for the SOE's costs, we assume that the impact of cheap inputs and credits is sufficiently large to give the SOE a cost subsidy in the early transition phase.⁸

These features of the early transition phase are easily formalized through modification of the model presented in Section 2. The demand side of the market is unchanged. Since the SOE operates as a monopolist, the start-up is restricted to produce no output. Given this restriction, the SOE's de facto price as a function of its quantity-quality pair is derived by rewriting (3a) with $q^e = 0$: $p^I = m^I(a + b(X - d))$. The SOE's unit cost function is modified to include a factor s^C as a catch-all term for any effects due to interference in the firm's operations or due to subsidies: $c^I(m^I) = (1 - s^C)(m^I)^2$. Given the price and cost equations, the SOE's revenues and profits are calculated in the standard fashion.

Lemma 4 gives the SOE's optimal quantity-quality pair in the early transition phase, q_E^I and m_E^I , along with basic comparative static results for changes in s^C .

⁸We only care about the effects of government interference on variable costs, not fixed costs. This can lead to surprising results. For example, often times the SOE is required to maintain some level of employment. While this raises the firm's overall costs, it also shifts labor from a variable cost to a fixed cost (assuming the constraint is binding). This implies that an employment constraint decreases the SOE's unit costs, just like an input subsidy.

Lemma 4: For the early transition phase, the SOE's optimal quantity and quality are given by (7a) and (7b).

Ceteris paribus, an increase in s^c does not affect q_E^I and increases m_E^I .

$$q_E^I = \frac{a + bX}{3b} \quad (7a)$$

$$m_E^I = \frac{a + bX}{3(1 - s^c)} \quad (7b)$$

It follows from Lemma 4 that a change in government interference with the SOE during the early transition phase (as captured by s^c) affects the quality levels chosen by the SOE in the early transition phase. As argued previously, this implies an effect on the initial beliefs of the start-up following entry, and ultimately an effect on the likelihood of the high or low development outcomes.⁹

4. A Dynamic Model of Transition

In Section 2, we developed a static model of two firms competing in an industry with product differentiation. This model has two Nash equilibria which correspond to the high and low development outcomes. In this section we present a dynamic model of transition which is used to analyze the probability of selection of the high development equilibrium as a function of the extent of cost discrimination against the start-up, the extent of subsidization of the former SOE, the speed of transition and the timing of the start-up's entry during transition. We begin by discussing the adaptive learning model embedded within our dynamic model of transition, and then turn to a description of the simulations of our dynamic model of transition.

Adaptive Learning: Underlying our dynamic model of transition is a model of firm level behavior in which managers are boundedly rational. In this model, managers are uncertain about their opponent's likely actions and unable to optimize perfectly. Over time, firms build up beliefs about their opponents' actions based on observed

⁹While we concentrate on cost subsidies, our results extend naturally to the case where the firm receives an output subsidy (or tax). With both cost and output subsidies, an increase in the cost subsidy decreases q_E^I and increases m_E^I , while an increase in the output subsidy has exactly the opposite effect.

past behavior, and slowly learn to play optimally given their beliefs. This gives rise to a dynamic process which eventually, if it converges, leads to an equilibrium. For the differentiated product duopoly model described in Section 2, the dynamic process always converges, allowing us to solve the selection problem between the high and low development equilibria.

Using an adaptive learning model is a substantial departure from standard approaches to resolving selection problems in applied game theoretic models. In doing so, we provide one of the first applications for the burgeoning learning literature in game theory. Our model is designed to capture two stylized features of adaptive learning. These features are especially relevant for modeling naive players facing complex, chaotic situations -- a description which certainly fits the managers of firms in Eastern European transitional economies.

1) Choices are history dependent. Players condition their beliefs about their opponent's current play on the observed history of play. Instead of attempting to reason ahead about what strategies their opponent will follow, players use past play as the best guide to future behavior. Transitory changes in the game can have permanent effects through altering the early play upon which beliefs are based.

In transition, neither SOEs nor start-ups are likely to immediately know what strategy their opponents will use. An SOE facing an unfamiliar start-up will not know either what the new firm's payoffs are or how the new firm makes decisions. While a start-up has more information to draw upon, it faces similar problems in evaluating the motivation and decision making of the SOE -- the SOE is an unfamiliar opponent acting in a new situation. Given this strategic uncertainty, assuming that managers rely on past play in forming conjectures about current actions is highly plausible.

It is the history dependence of the adaptive learning model which allows us to generate predictions which are unavailable from more standard approaches. By the very nature of transition, the economic environment is rapidly changing. It is plausible that the environment in which transition takes place has a long run impact on which equilibrium emerges, but, beyond informal stories about focal points, standard models leave no room for history dependence in equilibrium selection. In contrast, history dependence is an integral part of an adaptive

learning model, allowing us to formally capture the effects of conditions during transition on the long run efficiency of a transformed economy.

2) Players have limited computational and reasoning ability. Computational abilities come into play in two ways. First, in the discrete version of the game used in these simulations, each player has 10,000 available strategies. The sheer size of the game makes calculating a best response a daunting task.¹⁰ Second, the profit function has discontinuities which complicate calculations even for the continuous version of the game. These discontinuities make calculating an expected profit for a diffuse prior over opponent's strategies difficult. Maximizing expected profits is an even tougher problem. Given the computational complexity involved in trying to calculate a best response, we treat players as approximately maximizing their expected payoffs in any given period, slowly working towards a true maximum via a process of trial and error.¹¹

In transition, the inexperienced managers of former SOE's and start-ups face extremely complex problems in a chaotic setting. Even if these managers faced no strategic uncertainty, it is likely that they would be unable to immediately find their optimal strategy. Therefore, abandoning the perfect optimization embedded in standard models of optimization is quite reasonable.

The inability of managers to perfectly optimize plays an important role in interpreting our results. This inability generates endogenous variation within our model. We therefore make statements in terms of probability distributions over the equilibria, rather than computing basins of attraction for the two equilibria. This implies that changes in the environment of transition will generate continuous changes in the probability of the high development equilibrium, rather than discontinuous changes when the border of a basin of attraction is crossed. Continuity of response indicates that changes in the environment of transition can have an effect even if the

¹⁰ See Mookherjee and Sopher (1993) for experimental evidence that complexity affects how games are played.

¹¹ See Merlo and Schotter (1994) for experimental evidence that subjects use an adaptive approach to solving relatively difficult decision problems.

dynamics are not balanced on a knife's edge between the two equilibria, allowing us to meaningfully talk about the marginal cost/benefits of changes in the environment for transition.

The adaptive learning model employed by our computer simulations is a modified version of fictitious play. This is among the best-known models of adaptive play in existence.¹² Implementing an adaptive learning model raises a major disadvantage of the adaptive approach: the excessive degrees of freedom it can give a modeler. In choosing what features to incorporate into our model, we have tried to be guided by the growing experimental literature on learning. While the approaches to learning of managers in Eastern Europe and experimental subjects no doubt differ, experiments are virtually our only source of controlled data on how people learn. Easing our computational difficulties also played a major role in our decisions. While there is no reason to believe we have developed the canonical learning model, our main results would not have differed greatly with small changes to the details of the model.

Simulations: We now give an overview of the simulations of our dynamic model of transition. For additional details beyond those provided below, see Appendix B.

Each simulation consists of three phases: the early transition phase, the mid-transition phase, and the late transition phase. The numbers of rounds in the early transition phase and the mid-transition phase are determined by the random variables ER and MR. These are drawn from uniform distributions over the integers in the intervals [10,150] and [10,60] respectively. The late transition phase lasts for $110 - MR$ rounds.

The SOE is a monopolist in the early transition phase and receives a unit cost subsidy of s^c . The amount of this subsidy is drawn from a uniform distribution over the interval [0, .20]. Since there is no strategic uncertainty to be resolved, the SOE only needs to solve an optimization problem. In each period, the SOE draws

¹²See Fudenberg and Levine, ch. 2 (1996) for a discussion of the fictitious play literature. As an alternative to fictitious play, we could have used a reinforcement based model. Such models assume even less reasoning ability on the part of players than fictitious play; players do not maximize versus some probability distribution over their opponent's strategies, but instead tend to choose the strategies which have yielded the highest payoffs in the past. Using a reinforcement-based model would affect our results. In these models, players only learn when they actually are playing. Thus, the SOE's behavior prior to entry would not affect the entrants' behavior, lessening the effects of subsidizing the SOE. See Fudenberg and Levine, ch. 3 (1996) for a discussion of reinforcement based learning models.

a random sample of 99 quantity-quality pairs and calculates the profit for each. If the previous period's quantity-quality pair yield a higher payoff than all of the strategies in the sample, it is chosen again. Otherwise, the most profitable quantity-quality pair in the random sample is chosen. This simple process of trial and error learning eventually converges to the optimal monopoly solution.

Entry takes place at some date t^E during the mid-transition phase. Following entry, both firms are free to produce positive output. The time of entry is exogenous and is randomly drawn from a uniform distribution over the number of periods in the mid-transition phase. An exogenous entry date might reflect some change in government policy, or simply the availability of a suitable entrant.¹³

In the mid-transition phase input and credit markets are underdeveloped. Reflecting this, the SOE receives a unit cost subsidy while the start-up faces cost discrimination. As the market replaces the old system of bureaucratic allocation, the SOE's cost subsidy decreases at a linear rate; in the t^{th} period of the mid-transition phase, the SOE receives a subsidy of $s^C \times (MR - t)/MR$. Upon entry, the start-up faces cost discrimination which increases its unit cost above αm^2 . For convenience, we model the amount of cost discrimination as being equal to the subsidy received by the SOE. Therefore, in the t^{th} period of the mid-transition phase, the start-up's unit cost equals $\alpha + (s^C \times (MR - t)/MR)$. We refer to the sum of the subsidy received by the SOE and the cost discrimination faced by the start-up as the *net cost distortion*.¹⁴ Once the economy moves into the late transition phase, input and credit markets are fully developed and there is no net cost distortion.

Following entry, the difficulty of the learning problem facing the SOE and the start-up increases considerably. Not only do the firms need to learn how to optimize, they must also resolve their strategic uncertainty about their opponent's behavior. Each firm's behavior can therefore be broken into two components, selection of a strategy subject to beliefs and belief formation.

¹³Entry time could equally well be modeled as an endogenous variable. See Berkowitz and Cooper (in preparation).

¹⁴Our results depend primarily on the net cost distortion, not on the distribution of this distortion between the SOE and the start-up. Thus, setting the cost discrimination faced by the start-up equal to the subsidy received by the SOE is a purely cosmetic choice.

In each round, both firms must select a quantity and a quality level. We use a discrete strategy space with 100 quantity levels and 100 quality levels for a total of 10,000 possible strategies. To choose a strategy, each player selects a sample of 100 candidate strategies. This sample includes the past period's strategy and 99 strategies drawn at random.¹⁵ For each candidate strategy, the firm calculates an expected payoff using its beliefs about its opponent's strategy. The candidate strategy with the highest expected payoff is then selected.

Beliefs consist of a probability weighting given to each of the opposing firm's possible strategies. Following our conjecture that managers will base their expectation of current behavior on past behavior, initial beliefs following entry are based on observed behavior prior to entry. For the start-up, beliefs are based on the SOE's choices prior to entry. The SOE's past observations are of a lack of competition, incorporated into its beliefs as weight on the start-up producing no output. This implies that the SOE will be slow to respond to an increase in competition.¹⁶ Following entry, each period ends with beliefs being updated. Beliefs are updated by adding weight to the strategy just played by the opposing firm, decreasing all other weights proportionally.

For any normal form game where the simulation converges, the steady state must be a Nash equilibrium.¹⁷ Due to the learning model's similarity to fictitious play, there exists no general proof of convergence, and, because of its discontinuities, the differentiated duopoly model does not fit into any of the general categories of games for which it can be proved fictitious play converges. However, all of the simulations we ran converged to one of the two Nash equilibria. Given the large number of simulations involved, non-convergence is at best and extremely rare event.

¹⁵If a player has used the same strategy for ten consecutive rounds, its sample is limited to the past period's strategy and the eight adjacent strategies. Intuitively, this marks a switch from searching globally for an optimal strategy to fine tuning a rule of thumb. As a practical matter, this switch speeds up the simulations considerably without affecting which equilibrium emerges.

¹⁶This assumption is consistent with the traditional picture of SOEs as cumbersome behemoths which only respond slowly to change. Assuming that the SOE has more diffuse beliefs following entry or that the SOE is very quick to change its beliefs following entry would not affect our main qualitative results.

¹⁷Any steady state must be a self-confirming equilibrium, as defined by Fudenberg and Levine, 1993. Fudenberg and Levine prove that any SCE for a normal form game must be a Nash equilibrium.

5. Simulation Results

The primary purpose of this paper is to model the links between the environment in which transition occurs and the long run occurrence of the high or low development outcomes for a transition economy. Our dynamic model us to vary the environment in which transition occurs in a number of ways. By adjusting ER, the number of rounds in the early transition phase, and MR, the number of rounds in the mid-transition phase, we control the speed of transition. Changing s^c , the size of the initial net cost distortion, alters the initial cost distortion due to bureaucratic interference and underdeveloped input and credit markets. Modifying t^e , the period in which entry takes place, adjusts the speed of entry. In this section, we statistically analyze simulation results from our adaptive learning model to determine the effects of varying these four parameters on the probability of the high development outcome. Based on this analysis, we conclude that slow transition and high initial cost distortion reduce the likelihood of the high development outcome emerging in the long run. However, delayed entry increases the likelihood that the high development equilibrium emerges.

Before examining the effects of changing ER, MR, s^c , and t^e , we ran two sets of 1000 baseline simulations. These simulations were designed to test the simulation program and to guarantee that our adaptive learning model converges to a Nash equilibrium in a reliable fashion. For all of these simulations, we eliminated the early and mid-transition phases ($ER = MR = 0$) and allowed the SOE and start-up equal access to fully developed input and credit markets ($s^c = 0$). All of these simulations were run for 200 rounds to allow greater convergence to equilibrium. For all 2000 baseline simulations, we observed convergence to a Nash equilibrium. Moreover, we observe no cases in which a simulation was close to one Nash equilibrium following 100 rounds and then switched to the other equilibrium following 200 rounds. Therefore, even though not all of our simulations are completely converged to equilibrium when we simulate the full model, we can be confident that all of the simulations would eventually converge with more rounds of play. In the first set of baseline simulations the two firms were symmetric ($\alpha = 1.0$). The incumbent took on the high quality role (in the long run) for 514

of 1000 runs; this is not significantly different than the 50% predicted by theory.¹⁸ This demonstrates that the simulation program fulfills a basic prediction of the adaptive learning model, and is not inherently biased in favor of one firm taking on the high quality role in the long run. In the second set of baseline simulations, the equilibrium in which the entrant takes on the high quality role was Pareto efficient ($\alpha = .9$). This high development outcome emerged for 996 of 1000 simulations. This result establishes that any significant departures from the high development outcome (with $\alpha = .9$ in the long run) are due to aspects of the environment in which transition occurs rather than some inherent feature of the simulation program.

Having established that the simulation program is well-behaved, we turn to the effects of adjusting ER, MR, s^c , and t^E on the probability of the high development outcome. Henceforth, all simulations are of the full dynamic model of transition, as described in Sections 2 - 4. Implicitly, the probability of the high development outcome in our adaptive learning model is a function of the four variable parameters in the model: $p_H = f(ER, MR, s^c, t^E)$. While there is no analytical method for finding this function, we can statistically approximate it. We ran 30,000 simulations of the dynamic transition model with independently drawn values for ER, MR, s^c , and t^E . For each simulation, we observed whether play converged to the high development or low development outcome. All of the simulations were within two grid points of an equilibrium, and thus would almost certainly have converged eventually given our baseline results. Since there is no theoretical reason to believe that $f(ER, MR, s^c, t^E)$ has some specific functional form, we used a well known functional form which is easy to interpret. Specifically, we ran probit regressions. For all of the regressions, an observation consisted of a single simulation. The dependent variable was whether or not the high development outcome occurred in the long run (0 = low development outcome, 1 = high development outcome). We ran a number of specification for the independent variables, using various combinations of ER, MR, s^c , and t^E . Table 2 reports three basic regressions. While we ran a number of

¹⁸The estimated frequency for the incumbent taking on the high quality role is .514 with a standard deviation of .0158. Testing the null hypothesis that the frequency is .500, we get a z-score of .886. The null cannot be rejected at standard levels of significance.

fancier specifications, some of which fit the simulated data significantly better, none provided any substantial insight into the simulation results beyond that provided by the regressions in Table 2.

(Table 2 here)

Regression 1 is a linear specification. This simple regression gives a nice overview of the main results. The only parameter which is not significant at the 1% level is ER. Increases in either MR or s^C decrease the probability of the high development outcome while an increase in t^E increases this probability. This linear regression captures our most important results: A decrease in the speed of transition, as measured by MR, will decrease the likelihood of the high development outcome. An increase in cost distortion due to government interference or imperfect input and credit markets, as captured by s^C will also decrease the likelihood of the high development outcome. A delay in the time of entry holding the speed of transition otherwise fixed, as captured by t^E , increases the probability of the high development outcome.

A more detailed picture of the relationship between ER, MR, s^C , and t^E and the likelihood of the high development outcome can be seen by looking at Regression 2. This specification differs from Regression 1 through the inclusion of interaction terms among the four independent variables.

Regression 2 is still dominated by MR, s^C , and t^E . The interaction terms between ER and MR and between ER and t^E are marginally significant individually, but cannot even break the 10% threshold for joint significance.¹⁹ Interestingly, MR is no longer significant by itself, but only in combination with s^C and t^E . All three of the interaction terms between MR, s^C , and t^E are significant at the 1% level. The interaction terms between MR and s^C and between s^C and t^E tell the same story. Both speeding transition and delaying entry increase the likelihood of a high development outcome by reducing cost distortion at the time of entry. If there is little cost distortion to begin with, the effect of either policy is reduced. Additional regressions suggest that

¹⁹A log-likelihood ratio test with two degrees of freedom yields $\chi^2 = 1.608$.

the negative interaction term between MR and t^E is an artifact of the specification with little economic relevance.

20

Regression 3 examines why ER is not significant in the other two regressions. This specification differs from Regression 1 by including a squared term for ER. The parameter estimates for both ER and ER^2 are significant at the 5% level, and the two parameters are jointly significant at 5% level.²¹ The quadratic specification can detect the effect of ER when the linear cannot because this effect is non-monotonic. For low values of ER (holding MR, s^C , and t^E fixed) the marginal effect of ER on the probability of a high development outcome is negative. For high values of ER, this marginal effect is positive. Overall, ER is only of secondary importance in determining the likelihood of the high development outcome. It speaks volumes that this variable can barely crack the 5% threshold with 30,000 observations.

To understand how ER, MR, s^C , and t^E affect the probability of the high development outcome, we turn to the dynamics of the simulations. In this explanation, we concentrate on the fine details of a small number of simulations in which only s^C is varied. Having understood this highly constrained example, the full results are interpreted by analogy.

Figures 1 and 2 illustrate the outcomes of two sets of 100 simulations. For all of these simulations, we set $ER = 80$, $MR = 35$, and $t^E = 18$. These are the average values of each variable in the full model (rounded to the nearest integer). For the simulations in Figure 1 $s^C = .05$, while Figure 2 depicts simulations with $s^C = .15$. These numbers are 50% and 150%, respectively, of the average value for s^C . For each set of simulations, the distributions of outcomes are shown for the period following entry, ten periods following entry, twenty periods

²⁰Additional regressions suggest that the negative interaction term between MR and t^E is an artifact of the specification with little economic relevance. We ran specifications which substituted t^E/MR for t^E . This change in the specification had no impact on our major conclusions. The interaction term between time of entry and MR is significant and positive (rather than negative) when t^E/MR is used. Economically, this makes sense -- the slower transition is, the more beneficial a delay in entry is. Generally, the specification with t^E rather than t^E/TR gives a better fit; the absolute value of the log likelihood was generally lower using t^E rather than t^E/MR .

²¹A log-likelihood ratio test with two degrees of freedom yields $\chi^2 = 6.602$.

following entry, and fifty periods following entry. Solid dots (●) represent quantity-quality pairs for the SOEs while hollow dots (○) represent quantity-quality pairs for the start-ups.

As the regressions would suggest, simulations with $s^c = .05$ converge to the high development outcome much more frequently than simulations with $s^c = .15$ (91 efficient outcomes vs. 6 efficient outcomes). Differences in the simulations prior to entry play a major role in this result. During the early transition phase, play in both sets of simulations converges toward the profit maximizing quantity-quality pairs of (3.33,7.02) with $s^c = .05$ and (3.33,7.84) with $s^c = .15$. Thus, throughout the early transition phase the start-ups observe higher quality levels (on average) with $s^c = .15$ than with $s^c = .05$. As cost distortion declines during the mid-transition phase, quantity and quality gradually decrease for SOEs in both sets of simulations. None the less, quality is always higher (on average) in the simulations with $s^c = .15$. At the time of entry, average quality is 7.34 in the $s^c = .15$ simulations as opposed to 6.94 in the $s^c = .05$ simulations. Since start-ups' initial beliefs are based on the SOEs' play prior to entry, at the time of entry start-ups in $s^c = .15$ simulations anticipate higher quality than start-ups in $s^c = .05$ simulations.

As a general rule, firms which expect to face opponents producing high quality goods maximize profits by producing low quality goods and vice versa.²² Additionally, firms with relatively high marginal costs (*ceteris paribus*) optimally produce lower quality goods. These two observations drive the initial choices of start-ups. With $s^c = .15$, the start-ups enter with beliefs that the SOEs will produce relatively high quality goods, since this is what occurs prior to entry. The cost distortion faced by start-ups is relatively severe, resulting in (temporarily) high marginal costs. Both factors push the start-up toward producing low quality goods. Indeed, in all 100 simulations with $s^c = .15$, the start-up's initial quality is less than the SOE's. With $s^c = .05$, the start-ups observe lower levels of SOE quality prior to entry and face less cost distortion. Both of these factors make it less likely

²²This is true only in a global sense, not a local sense. For example, suppose the SOE's best response is to produce higher quality than the start-up. A marginal increase in the start-up's quality increases the SOE's optimal quality. However, if the start-up's quality is increased sufficiently, the SOE's optimal quality falls discontinuously below the start-up's quality.

that the start-up will initially produce low quality goods. As expected, for 21 of the 100 simulations with $s^C = .05$, the start-up's initial quality is *greater* than the SOE's. Thus, more start-ups enter in the high quality role associated with the high development outcome when $s^C = .05$ than when $s^C = .15$.

Following transition cost distortion continues to diminish as input and credit markets develop, increasing the attractiveness of producing low quality goods for the SOE and high quality goods for the start-up. Simultaneously, firms learn about the play of their opponents. For an SOE facing a start-up producing low quality goods, learning makes the production of high quality goods more attractive as a way of differentiating its product. An SOE facing a start-up producing high quality goods learn to produce lower quality goods for the same reason. As the SOE's quality levels change, analogous responses are seen in start-up choices. These reactions drive the dynamics. Suppose the start-up initially enters with higher quality than the SOE. This causes the SOE to decrease its quality beyond changes due solely to the decrease in subsidies over time. Falling costs and decreasing SOE quality both reinforce the start-up's selection of the high quality role. Play converges smoothly to the high development outcome. Suppose the start-up initially enters with lower quality than the SOE. In spite of its increasing costs, the relatively low quality of start-up goods leads to a slight increase in the quality of SOE goods. For example, over the first ten rounds following entry in the $s^C = .15$ simulations, average SOE quality increases from 7.34 to 7.42. While falling costs encourage the start-up to produce high quality goods, this is counter-balanced by the continued high quality of SOE goods. Whether or not the high development outcome emerges depends on the relative strengths of these two forces. In some simulations, the start-up never switches to the high quality role, and play gets stuck in the low development outcome.

The preceding analysis illustrates why the high development outcome is more frequent in the $s^C = .05$ simulations than the $s^C = .15$ simulations. All simulations in which the start-up enters producing high quality goods eventually converge to the high development outcome. There are 21 such entries in the $s^C = .05$ simulations, but none in the $s^C = .15$ simulations. Simulations in which the start-up enters producing low quality goods are more likely to converge to the high development outcome with $s^C = .05$ than with $s^C = .15$ for two

reasons. Cost distortion following entry is always lower when $s^c = .05$. Therefore, the start-up always has greater incentives (holding beliefs fixed) to switch to production of high quality goods when $s^c = .05$. Less cost discrimination also means that the SOE is producing lower quality goods on average in all periods. For example, ten periods after entry in simulations where the start-up took the low quality role, the average SOE quality is 7.04 when $s^c = .05$ and 7.42 when $s^c = .15$. Therefore, on average start-ups will anticipate lower SOE quality in $s^c = .05$ simulations, making the high quality role more attractive. Both relatively low start-up costs and relatively low SOE quality with $s^c = .05$ make it more likely that a start-up which initially produces low quality goods will switch to the high quality role. Indeed 89% of start-ups which initially produce low quality goods eventually switch to production of high quality goods when $s^c = .05$, as opposed to only 6% when $s^c = .15$. To summarize, with $s^c = .05$ the start-up is more likely to enter in the high quality role and is more likely to switch to the high quality role if it enters in the low quality role.

Our analysis for the preceding example extends to the general model. The key insight is that long run outcomes depend critically on cost distortion *at the time of entry*. Any policy which decreases cost distortion at the time of entry is likely to increase the probability of the high development equilibrium. With relatively low cost distortion at the time of entry, the start-up believes it will face relatively low quality from the SOE and has relatively low costs for producing high quality goods. Both factors make it more likely that the start-up will enter in the high quality role or will switch to this role eventually. Even though all of the policies we study are transitory in nature, all have a long run effect through their impact on the formation of beliefs underlying the long run equilibrium.

The preceding insight underlies all of our major results. Decreased net cost distortion, as measured by s^c , directly affects the cost distortion at the time of entry. Suppose that transition is relatively fast (MR is large). While initial cost distortion is not affected, it now takes less time for the cost distortion to vanish. Holding the time of entry fixed, this means that cost distortion at the time of entry will be lower. Moreover, holding cost distortion at the time of entry fixed, cost distortion in the critical periods immediately following entry will be

decreased (because cost distortion falls rapidly). Both of these factors affect belief formation so the high development equilibrium becomes more likely. The later entry occurs, the lower cost distortion will be at the time of entry, leading to the high development equilibrium. Intuitively, startups are more likely to take on their natural role as high quality producers if market institutions are allowed to develop before entry takes place.

While delayed entry increases the likelihood of the high development equilibrium in the long run, it causes a loss of total surplus in the short run. As an example, we ran two sets of 100 simulations. For all of these simulations, we set $ER = 80$, $MR = 35$, and $s^C = .10$. These are the average values of each variable in the full model. In one set of simulations we set $t^E = 10$ and in the other we set $t^E = 25$. These parameter values represent fast and slow entry respectively. For each set of simulations we calculated average total surplus for each period. In periods when entry had only occurred in the fast entry simulations, these simulations yielded much higher average total surplus. Once equilibrium emerged, the slow entry simulations exhibit greater average total surplus reflecting a greater proportion of high development outcomes (consistent with the regressions). We then summed discounted average total surplus over all periods. For discount rates greater than .995, the slow entry simulations had greater sums of discounted average total surplus than the fast entry simulations. For lower discount rates, this result reversed.²³

Intuitively, competition emerges more rapidly with fast entry, and even bad competition is better than no competition. Thus, the timing of entry is subject to a clear tradeoff between short-run and long-run surpluses. In settings where there exists intense pressure to produce quick results, fast entry might be optimal even though it has a negative impact in the long run. Reducing cost distortion and speeding transition are unambiguously beneficial, increasing total surplus in both the short and long runs.

Increasing the length of the early transition phase has an ambiguous impact on the likelihood of the high development outcome because it has two effects in opposite directions. One effect is to strengthen the start-ups'

²³To give some feel for the numbers, suppose each period represents a month. The cutoff is then equivalent to an annual interest rate of 6.2%.

initial beliefs that the SOE will produce high quality goods. This effect reduces the likelihood that the start-up will take the high quality role. The other effect of increasing ER is to strengthen the SOE's beliefs that it will act as a monopolist. This slows any increase in the SOE's quality following entry, which in turn increases the likelihood that the start-up will take the high quality role. The marginal impact of an increase in ER depends on the relative strengths of these two forces -- the first dominates when ER is small, and the second dominates when ER is large.

To summarize, slowing transition (increasing MR), increasing net cost distortion (increasing s^c), and speeding entry (decreasing t^E) all increase the likelihood of the low development outcome. These results are driven by the impact of the environment in which transition occurs on play during transition. If there exists high cost distortion during transition, encouraging the SOE to initially produce relatively high quality goods and the start-up to initially produce relatively quality goods, the resulting beliefs are likely to yield the low development outcome.

6. Conclusions

This paper applies recent developments in adaptive theory to make predictions about the behavior of start-ups and restructuring SOEs in transition. The adaptive learning approach is employed to capture a chaotic transition environment in which boundedly rational firms are learning to compete against each other in an attempt to maximize profits. Since each firm looks to the past in order to derive its best current strategy, transient subsidization of an SOE, temporary cost discrimination against a startup and the level of development in input and credit markets when the start-up enters all have an impact on firms' beliefs about how best to maximize profits. These temporary events can distort beliefs of each firm in a way which pushes the market to a low development equilibrium in the long run.

To date, privatization has received the lion's share of attention in the field of transition economics. However, in many transition economies, including the very successful case of Poland, privatization has proceeded

very slowly. Furthermore, in some of the most successful economies, start-ups and spin-offs which operate outside the state allocation system have taken on a significant market share and raised the overall quality of goods and services. Our paper suggests that start-ups should enter only when input and credit markets are well developed. If the government can influence the timing on entry, then entry should be delayed until it is possible for start-ups to have almost the same access to inputs and credits that SOEs enjoy. Additionally, policies which accelerate the development of input and credit markets should be particularly effective in pushing the market into an efficient long run outcome.

References

- Aghion, P., Blanchard, O., and Burgess, R. (1994), "The Behavior of State Firms in Eastern Europe, pre-Privatization," *the European Economic Review* 38: 1327-49.
- Aslund, A. (1997), "Observations on the Development of Small Private Enterprises in Russia," *Post-Soviet Geography and Economics* XXXVIII: 191-206.
- Benacek, V. (1995), "Small Business and Private Entrepreneurship During Transition", *Eastern European Economics*, March/April, 33: 38-75.
- Berg, A. (1994), "Does Macroeconomic Reform Cause Structural Adjustments? Lessons from Poland", *Journal of Comparative Economics*, 18, 376-409.
- Berkowitz, D. (1993), "A Simple Model of an Oligopolistic Parallel Market," *Journal of Comparative Economics*, 17, 92 - 112.
- Blanchard, O., and Kremer, M. (1997), "Disorganization", William Davidson Institute, Working paper 38 and forthcoming, the *Quarterly Journal of Economics*.
- Brandts, J. and Holt, C. (1994), "Naive Bayesian Learning and Adjustment to Equilibrium in Signalling Games", mimeo, University of Virginia.
- Cannon, L.S. (1995), "Polish Mass Privatization-The Debate Goes On", *Transition* 6 (4), pp.7-8.
- Cheung, Y. and Friedman, D. (1994), "Learning in Evolutionary Games: Some Laboratory Results", mimeo, University of California, Santa Cruz.
- Cooper, D. J., Garvin, S., and Kagel J.H. (1994a), "Signalling and Adaptive Learning in an Entry Limit Pricing Game", mimeo, University of Pittsburgh.
- Cooper, D. J., Garvin, S., and Kagel, J. H. (1994b), "Adaptive Learning vs Equilibrium Refinements in an Entry Limit Pricing Game", mimeo, University of Pittsburgh.
- Crawford, V. (1995), "Adaptive Dynamics in Coordination Games", *Econometrica* 63 (1), 103-144.
- Earle, J., and Rose R. (1996), "Ownership Transformation, Economic Behavior and Political Attitudes in Russia", mimeo, Stanford Institute of Theoretical Economics, Stanford, CA, May 17.
- Erev, I. and Roth, A. E. (1995), "On the Need for Low Rationality, Cognitive Game Theory: Reinforcement Learning in Experimental Games with Unique, Mixed Strategy Equilibria", mimeo, University of Pittsburgh.
- European Bank for Reconstruction and Development (1995), *Transition report 1995*. European Bank for Reconstruction and Development, London.

Table 1

| Equilibrium Outcomes with Continuous Strategy Spaces $a = 0, b = 2, X = 10$ | | | | | | | | |
|--|-------|-------|-------|-------|---------|---------|-----|-----|
| Incumbent Produces High Quality | | | | | | | | |
| Alpha | q_i | q_e | m_i | m_e | π_i | π_e | CS | W |
| 0.9 | 2.02 | 2.66 | 7.98 | 5.91 | 65.1 | 83.7 | 138 | 287 |
| 1.0 | 2.17 | 2.61 | 7.83 | 5.22 | 74.0 | 71.0 | 132 | 277 |
| Entrant Produces High Quality | | | | | | | | |
| Alpha | q_i | q_e | m_i | m_e | π_i | π_e | CS | W |
| 0.9 | 2.56 | 2.31 | 5.13 | 8.55 | 67.4 | 91.0 | 140 | 298 |
| 1.0 | 2.61 | 2.17 | 5.22 | 7.83 | 71.0 | 74.0 | 132 | 277 |

- Shelley, L.I. (1992), "Entrepreneurship: some legal and social problems". In B. Dallago, G. Ajani and B. Grancelli, eds., *Privatization and Entrepreneurship in Post-Socialist Countries*, pp.307-325. New York, NY: St. Martin's Press.
- Sheppard, M. (1994), "Constraints to Private Enterprise in the FSU: Approach and Application to Russia". In I.W. Lieberman, J. Nellis et al., *Russia: Creating Private Enterprises and Efficient Markets*, Washington D.C: the World Bank, the Private Sector Development Department, chapter 14.
- Webster, L.M. (1993a), "The Emergence of Private Sector Manufacturing in Hungary: A Survey of Firms." World Bank Technical Paper Number 229, the World Bank, Washington, D.C.
- Webster, L.M. (1993b), "The Emergence of Private Sector Manufacturing in Poland: A Survey of Firms." World Bank Technical Paper Number 237, the World Bank, Washington, D.C.
- Webster, L.M., and Swanson, D. (1993), "The Emergence of Private Sector Manufacturing in the Former Czech and Slovak Federal Republic: A Survey of Firms." World Bank Technical Paper Number 230, the World Bank, Washington, D.C.
- Zemplinerova, A. and Stibal, J. (1995), "Evolution and Efficiency of Concentration in Manufacturing," in J. Svejnar, Ed., *The Czech Republic and Economic Transition in Eastern Europe*, pp. 233-54. San Diego, CA and London:Academic Press.

Figure 1

Simulations with $s^c = .05$
Periods Following Entry

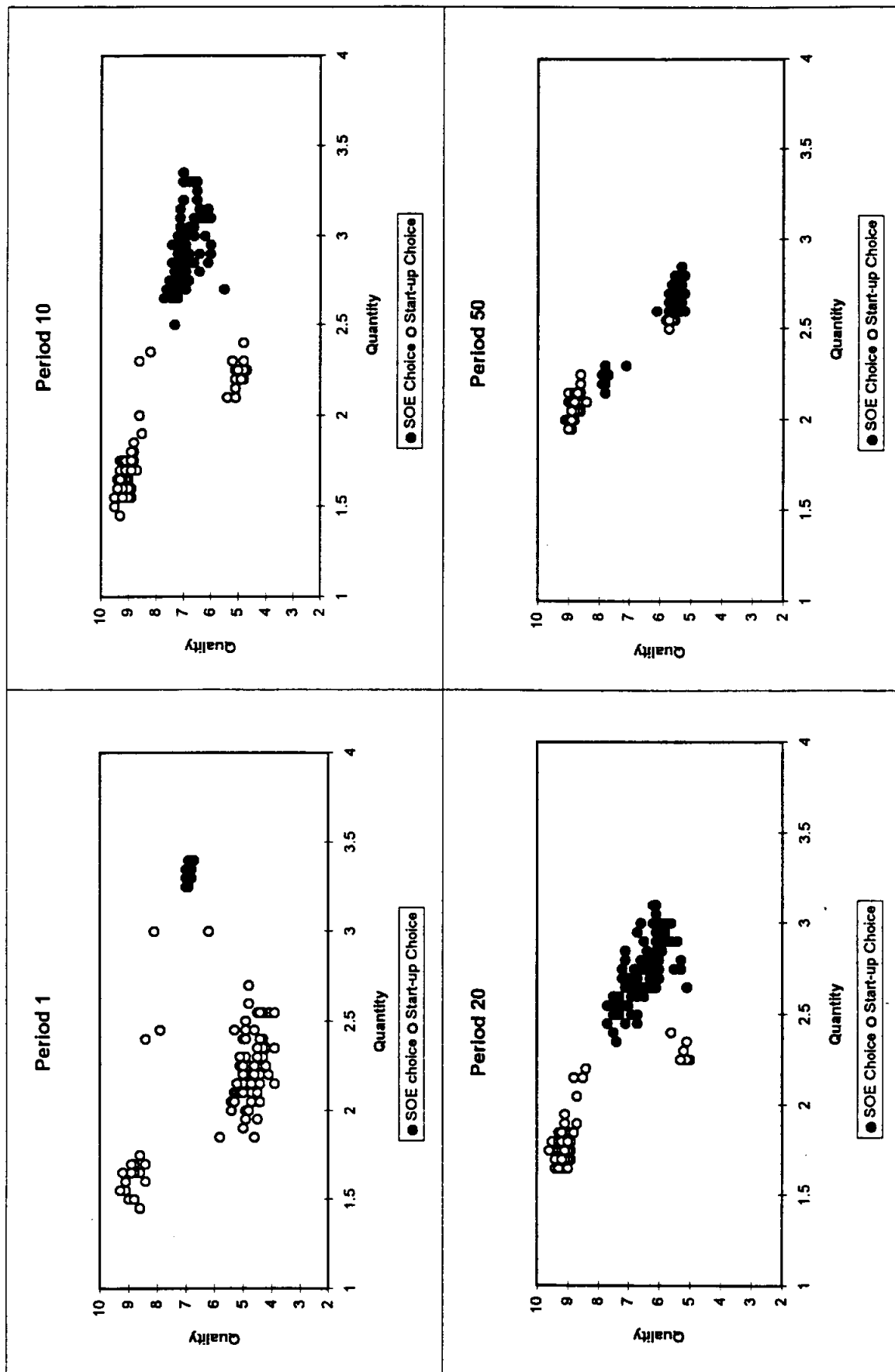


Table 2

| Fitted Approximation of Likelihood Function for High Development Outcome ¹ | | | |
|---|------------------------|-----------------------|-----------------------|
| Variable | Regression 1 | Regression 2 | Regression 3 |
| Constant | 2.8314** (63.385) | 1.5727** (15.520) | 2.9121** (52.145) |
| ER | .00021 (.846) | .00120 (1.197) | -.00247* (2.179) |
| MR | -.07082** (66.999) | .00246 (0.825) | -.07087** (67.008) |
| s^C | -23.048** (-90.684) | -12.356** (16.354) | -23.053** (90.670) |
| t^E | .11258** (83.046) | .06185** (12.213) | .11265** (83.043) |
| ER × MR | | -.00005* (1.940) | |
| ER × s^C | | -.00413 (0.636) | |
| ER × t^E | | .00007* (1.942) | |
| MR × s^C | | -.89014** (36.890) | |
| MR × t^E | | -.00053** (7.133) | |
| s^C × t^E | | .95122** (36.381) | |
| ER ² | | | .00002* (2.426) |
| Log Likelihood | -9896.043 | -8800.647 | |

- + significant at 10% level (2 tailed z-test)
- * significant at 5% level (2 tailed z-test)
- ** significant at 1% level (2 tailed z-test)

¹All regressions are standard probits. The terms in parentheses are z scores. The z-score equals the absolute value of the coefficient divided by the standard error.

Appendix A: Proofs of Lemmas 1-4

Proof of Lemma 1: The profit functions for the two firms are given by equations (8a) and (8b) when the SOE produces higher quality than the start-up and equations (9a) and (9b) when the start-up (entrant) produces higher quality than the SOE (incumbent):

$$\pi_h^I = \{m_h^I[a + b(X - q_h^I)] - bm_L^e q_L^e - (m_h^I)^2\}q_h^I \quad (8a)$$

$$\pi_L^e = \{m_L^e[a + b(X - q_h^I - q_L^e)] - \alpha(m_L^e)^2\}q_L^e \quad (8b)$$

$$\pi_h^e = \{m_h^e[a + b(X - q_h^e)] - bm_L^I q_L^I - \alpha(m_h^e)^2\}q_h^e \quad (9a)$$

$$\pi_L^I = \{m_L^I[a + b(X - q_h^e - q_L^I)] - (m_L^I)^2\}q_L^I \quad (9b)$$

The first order conditions when the SOE produces high quality than the start-up are given by (10a), (10b), (10c), and (10d):

$$\partial\pi_h^I/\partial q_h^I = m_h^I[a + bX] - bm_L^e q_L^e - (m_h^I)^2 - 2bm_h^I q_h^I = 0 \quad (10a)$$

$$\partial\pi_h^I/\partial m_h^I = \{a + b[X - q_h^I] - 2m_h^I\}q_h^I = 0 \quad (10b)$$

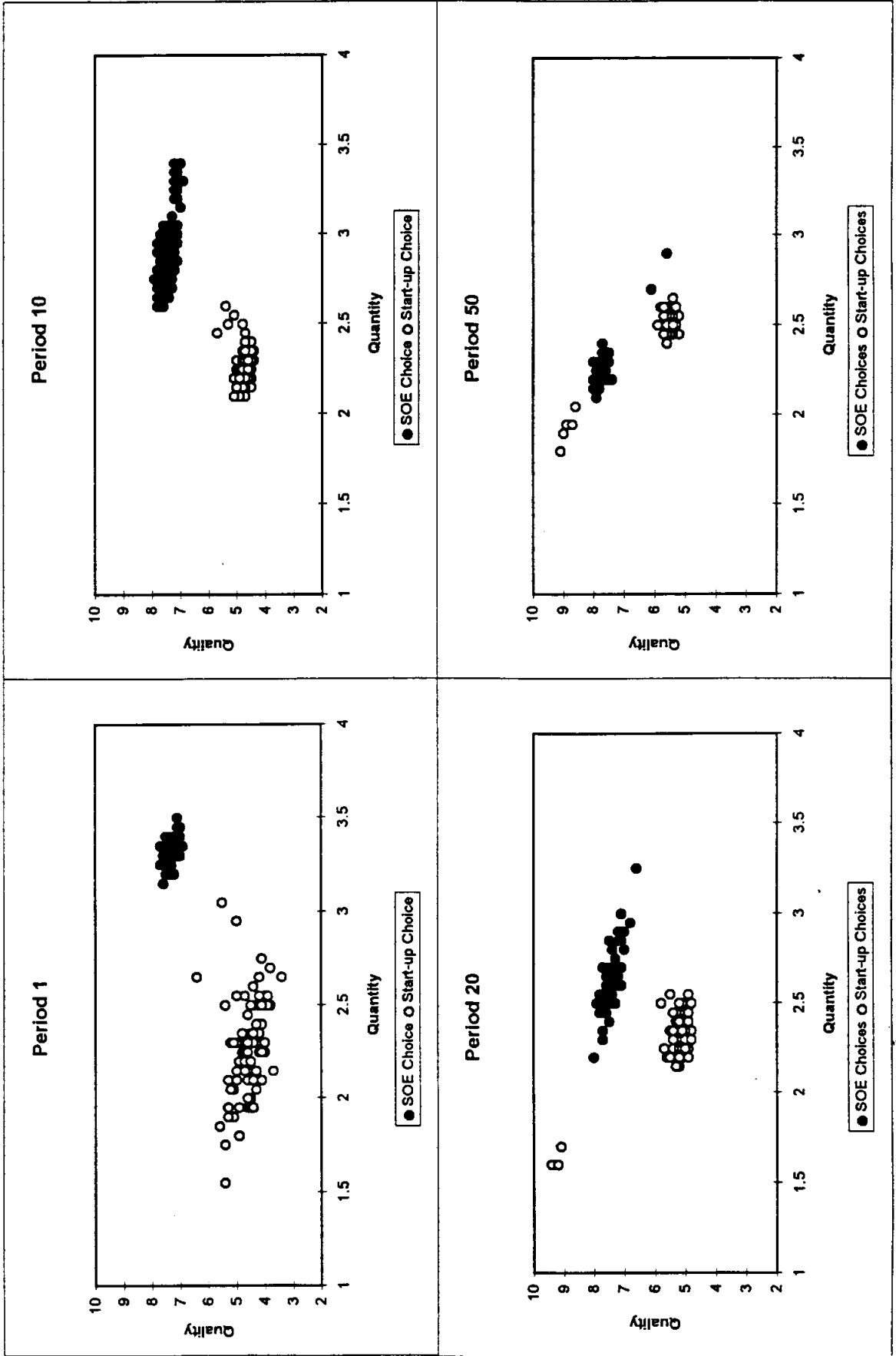
$$\partial\pi_L^e/\partial q_L^e = m_L^e[a + b(X - q_h^I)] - \alpha(m_L^e)^2 - 2bm_L^e q_L^e = 0 \quad (10c)$$

$$\partial\pi_L^e/\partial m_L^e = \{a + b[X - q_h^I - q_L^e] - 2\alpha m_L^e\}q_L^e = 0. \quad (10d)$$

Analogous first order conditions hold when the start-up produces high quality. Equilibrium strategies when the SOE produces high quality, $(q_h^I, q_L^e, m_h^I, m_L^e)$, as given in (4a - 4d), are found by

Figure 2

Simulations with $s^e = .15$
Periods Following Entry



objective function is quasiconcave, a unique solution exists. This solution is as follows:

$$m_d = bq_d = \left(\frac{a + bX}{9} \right) \left(\frac{63\alpha - 12}{27\alpha - 4} \right). \quad (12)$$

Using the definition of W_h^I ,

$$W_h^I = \left(\frac{(a + bX)^3}{27b} \right) \left(\frac{21\alpha - 4}{27\alpha - 4} \right)^3. \quad (13)$$

Combining this with π_h^I , as derived from (4a - d), gives

$$\text{sgn}(\pi_h^I - W_h^I) = \text{sgn}(243\alpha)(9\alpha - 4)^2 - (21\alpha - 4)^3. \quad (14)$$

Solving (14) numerically subject to the restriction from Lemma 1 that $2/3 < \alpha < 3/2$, $\text{sgn}(\pi_h^I - W_h^I) > 0$ for any $\alpha \in (.8285, 3/2]$, and is otherwise non-positive. Making analogous calculations, when the start-up produces the higher quality good, $\text{sgn}(\pi_h^e - W_h^e) > 0$ for any $\alpha \in [2/3, 1.207)$ and is otherwise non-positive. Therefore, the higher quality producer will not deviate from either equilibrium if $.8285 < \alpha < 1.207$.

Returning to the equilibrium in which the SOE produces high quality goods, consider the decision facing the start-up. We need to prove the start-up cannot profitably deviate by making a discontinuous leap to higher quality than m_h^I . If the start-up deviates and produces a higher quality good than the SOE, it solves the program

$$\begin{aligned} \max W_L^e &= (m_d[a + b(X - q_d)] - bm_h^I q_h^I - \alpha m_d^2) q_d \\ \text{s.t. } m_d &\geq m_h^I, q_d > 0. \end{aligned} \quad (15)$$

Solving this constrained maximization problem in the usual manner, the following solution is unique and satisfies the second order conditions:

solving the system of equations given by (9a - d). The equilibrium strategies when the start-up produces high quality, $(q_h^e, q_L^l, m_h^e, m_L^l)$, as given in (5a-5d), are found in an analogous manner. It is easily confirmed the second order conditions hold for both players in both equilibria.

As shown in Gal-Or ((1985) corollary 1, p.313), there is strict product differentiation in equilibrium. Thus, for both proposed equilibria to exist, m_h must be strictly greater than m_L in both cases. Substituting in the solutions for m_h and m_L given in (4c), (4d), (5c), and (5d) into $m_h > m_L$ gives the condition $2/3 < \alpha < 3/2$.

Our analysis is limited to equilibria in which the market is not covered. Substituting the solutions for q_h and q_L into the inequality $q_h + q_L < X$ yields (6). **Q.E.D.**

Proof of Lemma 2: To prove $.829 < \alpha < 1.207$, the set of α in which both equilibria exist is constructed. Consider the case in which the SOE produces the higher quality product. In deriving the equilibrium quantity-quality pairs, (4a - d), we only checked if players' strategies were locally optimal. Because the firms' profit functions (holding the opposing firm's quantity-quality pair fixed) need not be quasiconcave, a firm might still profitably deviate by making a discontinuous shift in its strategy. In particular, the SOE might jump to the low quality role or the start-up might jump to the high quality role. In the following calculations, we derive conditions under which such a deviation could not be profitable.

To begin, consider the SOE. In the proposed equilibrium, the SOE produces higher quality goods than the start-up. If the SOE deviates and produces a lower quality good than the start-up, it optimizes by solving the following problem:

$$\begin{aligned} \max_{q_d, m_d} W_h^l &= m_d q_d [a + b(X - q_L^e - q_d) - m_d] \\ \text{s.t. } m_d &\leq m_L^e, q_d > 0. \end{aligned} \tag{11}$$

This constrained maximization problem is solved in the usual fashion. Given that the local

Using (4a - 4d) to derive π_L^e and (5a - 5d) to derive π_h^e ,

$$\text{sgn}(\pi_h^e - \pi_L^e) = \frac{9(9 - 4\alpha)^2}{(27 - 4\alpha)^3} - \frac{216\alpha^2}{(27\alpha - 4)^3} \quad (20)$$

Analyzing (20) numerically, $\text{sgn}(\pi_h^e - \pi_L^e) > 0$ for any $\alpha \in [2/3, 1]$.

$$(ii) \quad \pi_h^l > \pi_L^l: \alpha \in [.939, 1]; \quad \pi_h^l < \pi_L^l: \alpha \in (.829, .939).$$

Using (4a - 4d) to derive π_h^l and (5a - 5d) to derive π_L^l ,

$$\text{sgn}(\pi_h^l - \pi_L^l) = \frac{(9\alpha)(9\alpha - 4)^2}{(27\alpha - 4)^3} - \frac{216}{(27 - 4\alpha)^3} \quad (21)$$

It follows from numerical calculations that $\text{sgn}(\pi_h^l - \pi_L^l) > 0$ if $\alpha \in (.939, 1)$ and $\text{sgn}(\pi_h^l - \pi_L^l) \leq 0$ if $\alpha \in (0, .939)$.

$$(iii) \quad \pi_h^e + \pi_L^l > \pi_h^l + \pi_L^e: \alpha \in (.829, 1).$$

The following equalities are derived from (4a - 4d) and (5a - 5d):

$$(\pi_h^e + \pi_L^l) = \frac{9(a + bX)^3((9 - 4\alpha)^2 + 24\alpha)}{\alpha b(27 - 4\alpha)^3} \quad (22)$$

$$(\pi_h^l + \pi_L^e) = \frac{9(a + bX)^3(\alpha(9\alpha - 4)^2 + 24\alpha^2)}{b(27\alpha - 4)^3} \quad (23)$$

The result then follows from numerical calculations. **Q. E. D.**

Proof of Lemma 4: The SOE's profit function in the early transition phase is given by (24).

$$\pi(q^l, m^l, s^C) = (m^l(a + b(X - q^l)) - (1 - s^C)(m^l)^2)q^l \quad (24)$$

Differentiating with respect to q^l and m^l , the SOE's first order conditions are given by (25a) and (25b).

$$m_d = \left(\frac{a + bX}{6\alpha} \right) \left(1 + \sqrt{\frac{(27 - 4\alpha)^2 - 108(9 - 4\alpha)}{(27 - 4\alpha)^2}} \right) \quad (16a)$$

$$q_d = \left(\frac{a + bX}{3b} \right) \left(2 - \sqrt{\frac{(27 - 4\alpha)^2 - 108(9 - 4\alpha)}{(27 - 4\alpha)^2}} \right). \quad (16b)$$

Using the definition of W_L^e ,

$$W_L^e = \frac{(a + bX)^3}{54\alpha b} * (1 + \psi(\alpha)) * (2 - \psi(\alpha))^2 \quad (17)$$

where

$$\psi(\alpha) = \sqrt{1 + \frac{108\alpha^2(9\alpha - 4)}{(27\alpha - 4)^2}} \quad (18)$$

Combining this with π_L^e , as derived from (4a - d), gives

$$\text{sgn}(\pi_L^e - W_L^e) = \text{sgn}(11,664\alpha^3 - (27\alpha - 4)^2(1 + \psi(\alpha))(2 - \psi(\alpha))^2). \quad (19)$$

Solving numerically, when the entrant produces the lower quality good, $\text{sgn}(\pi_L - W_L^e) > 0$ for any $\alpha \in (2/3, 1.23)$ and is otherwise non-positive. Similarly, when the incumbent produces the lower quality good, $\text{sgn}(\pi_L - W_L^e) > 0$ for any $\alpha \in (.813, 3/2)$ and is otherwise non-positive. Therefore, the lower quality producer in either equilibrium will not deviate if $.813 < \alpha < 1.23$. Combining this with the previous restriction ($.8285 < \alpha < 1.207$), and Lemma 2 follows. **Q. E. D.**

Proof of Lemma 3:

$$(i) \quad \pi_h^e > \pi_L^e: \alpha \in (.829, 1).$$

Appendix B: Detailed Description of the Simulation

This appendix discusses a number of technical details of the simulations which are passed over in Section 4. These are broken down into three categories: the strategy set, formation of beliefs, and selection of a strategy. It is assumed that the reader is already familiar with material in Section 4.

The Strategy Set: Feasible strategies are bounded below by zero. Quantity is bounded above by the market size; producing more than X can never give a positive profit. Quality is also bounded above by eliminating levels which can never give a positive profit. Note that the most a consumer with the highest possible preference for quality is willing to pay for a good of quality m is $m(a + bX)$. A firm can not earn a positive profit by producing quality m if $\alpha m^2 > m(a + bX)$. Doing some algebra, we see that any quality level $m > (a + bX)/\alpha$ must yield a negative profit. We eliminate all such quality levels. The remaining set of strategies are $q_i \in [0, X]$ and $m_i \in [0, (a + bX)/\alpha]$.¹

To keep the adaptive process tractable, discrete strategy sets are used rather than allowing a continuum of strategies. We originally subdivided the two preceding strategy sets into 200 intervals. Since a player can choose any available quantity or quality, this gave a total of 40,000 strategies. However, a preliminary run of 1000 simulations revealed that the upper half of the quantity and quality strategies were literally never used. We therefore limited players to the lowest 100 quantity and quality levels, giving a total of 10,000 available strategies. Given that the 30,000 eliminated strategies were never used, this had no quantitative or qualitative effect on our results. This elimination of strategies sped up the simulations considerably; we had previously used a much larger sample of strategies since 3/4 of the strategies being evaluated weren't viable candidates. For all of the simulations in this paper, we set $a = 0$, $b = 2$, and $X = 10$. Given these parameters and $\alpha = 1$, players' strategy sets are $\{0, .05, .1, \dots, 4.95\} \times \{0, .1, .2, \dots, 9.9\}$.

¹ See Cooper, Garvin, and Kagel (1994b) for evidence that at least some experimental subjects are able to recognize and eliminate dominated strategies. Given this ability, it seems likely that players could perform the far easier task of eliminating strategies which never yield positive payoffs.

$$m^l(a + bX - 2bq^l) - (1 - s^C)(m^l)^2 = 0 \quad (25a)$$

$$(a + b(X - q^l)) - 2(1 - s^C)m^l = 0 \quad (25b)$$

Solving these simultaneous equations yields two potential solutions. Of these two solutions, only the solution given by (7a) and (7b) fulfills the second order conditions for maximization. The comparative static results all follow directly from differentiating (7a) and (7b) with respect to s^C . Q. E.

D.

weighting rule.³

Prior to entry, the SOE builds up beliefs about a non-existent entrant. This can best be interpreted as the incumbent learning to expect that it will be a monopolist. We ran simulations in which post-entry history received discontinuously more weight than pre-entry history in determining beliefs. This has no effect on the qualitative results.

Strategy Selection: Initially, both firms use a random search algorithm to determine their strategies. Expected profits are calculated for a sample of 100 strategies. This sample consists of the previous period's strategy and 99 strategies chosen randomly from the strategy space. Expected profits are calculated via the following formula.

$$E\pi'_i(j,k) = \sum_{l=1}^{l=100} \sum_{m=1}^{m=100} \mu'_i(l,m)\pi(j,k,l,m) \quad (27)$$

The only source of uncertainty in the system is the strategic uncertainty each firm faces about the other's strategy choice. Each firm chooses the member of its sample which gives it the greatest expected profit. Prior to entry, the start-up is constrained to select the quantity-quality pair (0,0).

Starting the simulation requires an initial strategy for each player. The quantity-quality pair (0,0) was used for a starting point. Given that this pair yields a profit of zero, we expect it immediately to be discarded by all players in favor of a strategy which yields a positive expected profit. This was indeed the case for all of the simulations.

The choice of sample size was largely determined by considerations of computing speed. We wanted a sample size large enough to insure that a wide variety of strategies would be selected, but small

³ See Cheung and Friedman (1994) for an exercise in estimating a parameter for the rate of increase of weights. Their results suggest that weights should be exponentially increasing, although parameter values vary quite a bit between individuals. The specific parameter value we choose was largely arbitrary. By varying the exponential rate of growth, we can move from a noisy version of fictitious play to a noisy version of Cournot best-response dynamics.

Belief Formation: Each player is endowed with beliefs consisting of a probability distribution over the opposing player's strategies. (These probability distributions can also be called conjectures, according to taste.) Strategies are indexed with ordered pairs of integers from 1 to 100 for quantity and quality in the obvious fashion. Let $w_i^t(j,k)$ be the weight put by player I on its opponent using the quantity-quality pair (j,k) in period t , where $I \in \{I,e\}$. Let μ_i^t be the corresponding probability:

$$\mu_i^t(j,k) = \frac{w_i^t(j,k)}{\left(\sum_{x=1}^{100} \sum_{y=1}^{100} w_i^t(x,y) \right)} \quad (26)$$

We initialize $w_i^1(j,k) = 0$ for all $j \in \{1,2, \dots, 100\}$ and $k \in \{1,2, \dots, 100\}$.²

At the end of each round, beliefs are updated for each player. Suppose the SOE chooses the quantity-quality pair (j,k) in period t . The start-up's beliefs are updated according to the formula $w_e^{t+1}(j,k) = w_e^t(j,k) + e^{-(t-1)/10}$. Note that the start-up's weight on all quantity-quality pairs other than (j,k) is unchanged. The SOE's beliefs are updated in an analogous manner, with the start-up's strategy fixed at $(0,0)$ for all rounds prior to entry.

The exponential weighting in the updating rule means that more recent experience receives greater weight in beliefs. As a side effect, use of exponential weighting makes it less likely that the low development outcome occurs. (Emergence of the low development outcome depends on the early history of play. Exponential weighting decreases the relative weight of the distant past, reducing the effects of historical distortions.) Thus, it is especially striking that inefficiency arises with an exponential

²Presumably, firms initial beliefs are actually formed by their pre-transition experience. As such, the use of flat priors is a simplifying assumption. Given that beliefs are building up exponentially through the pre-entry phase, and only play an important role following entry, this assumption has little effect on the results. For technical reason, we put a very small initial weight on the pair $(0,0)$ for both firms.

enough that the simulations would run reasonably fast. Increasing the sample size results in play closer to the best response. This increases the speed of convergence, and decreases the variance of early period outcomes. Changing the sample size does not affect our qualitative results.

If both firms' strategies are identical for ten straight periods, firms switch from the random search algorithm to a hill-climbing algorithm. (The ten period count does not begin until entry has taken place.) In the hill-climbing algorithm, expected profits are calculated for the previous period's strategy and the eight surrounding strategies. The firm chooses the member of this set which yields the greatest expected profits. Once a firm starts hill-climbing, it always hill-climbs. Intuitively, if a firm has sampled almost one thousand strategies and found nothing better than its current choice, it must be near a maximum. It makes sense to finetune the current strategy rather than continuing searching broadly.