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TRADE POLICY AND INDUSTRIAL
SECTOR RESPONSES:
USING EVOLUTIONARY MODELS
TO INTERPRET THE EVIDENCE

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ABSTRACT

Firm- and plant-level empirical studies typically find that trade liberalization squeezes price-cost margins among import-competing firms, that this heightened competitive pressure induces productivity gains among these same firms, and that further efficiency gains come from market share reallocations. Using a computable industrial evolution model to simulate the dynamic effects of import competition, we demonstrate what types of managerial behavior, long-term transition paths and welfare effects are consistent with this set of stylized facts.

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I. Overview

Most students of economic development feel that liberal trade regimes are a good thing, and that the costs of protection can be substantial. In significant part, this belief traces to the notion that foreign competition disciplines domestic firms, forcing them to eliminate waste, accelerate their innovation rates, or shut down. This "import discipline" notion traces, in turn, to numerous firm- and plant-level empirical studies of liberalization episodes. These conclude that the manufacturing sectors of developing countries have become more efficient after trade liberalization episodes, that this has been accomplished partly through producer turnover, and that heightened competitive pressure from imports has been the motivating force.

Although the empirical literature that supports the import discipline hypothesis offers some robust findings, it leaves many basic issues unresolved. One source of ambiguity is that it is based on flawed measures of firm performance. But more fundamentally, this literature (a) fails to identify empirically the mechanisms that link import competition to efficiency, (b) only describes the short-run effects of trade liberalization, and (c) doesn't translate firms' performances into welfare measures. Our objective is to address these shortcomings. Using a computable industrial evolution model to simulate the dynamic effects of import competition, we demonstrate what types of managerial behavior, long-term transition paths, and welfare effects are consistent with the findings of previous firm- and plant-level empirical studies.

Our analysis is based on a modified version of Pakes and Ericson's (1995) and Pakes and McGuire's (1994) model—hereafter, the PEM model. It describes an industry populated by a changing set of firms, each producing its own differentiated product. New

1

firms enter the industry when the expected present value of their future earning stream exceeds their entry costs, and incumbent firms exit when the expected value of their future earnings stream falls below the scrap value of their assets. While active, firms can invest an amount of their choosing to increase the likelihood of a quality-improving product innovation. All economic agents make optimal choices, given their current information sets and the idiosyncratic shocks they experience. (Inter alia, these choices reflect accurate perceptions concerning the stochastic processes they optimize against and the behavior of their competitors.) We modify the PEM framework by introducing an imported product variety that competes with the domestically-produced varieties and increases in quality at an exogenous rate.

Simulations of our version of the PEM model reproduce the well-known features of short-run adjustment to trade liberalization by import-competing sectors: price-cost margins fall, and efficiency improves, largely because of the elimination of weak product lines and the exit of inefficient plants. But our results also demonstrate that the intra-industry efficiency effects of foreign competition are probably more nuanced than commonly believed.

Specifically, we find that productivity gains due to the purging of weak firms are transitory, and likely to dissipate within 10 to 15 years of trade liberalization. As they fade, the cumulative effects of reform-induced changes in the incentive to innovate become more important. These are often negative, so foreign competition can create a longer-term tendency for the quality of domestic goods to deteriorate relative to imports. Depending upon the nature of the trade reforms, this tendency may or may not be offset by quality/efficiency gains due to embodied technological progress in imported capital. In

any case, heightened import competition is likely to be accompanied by permanently

higher plant or product line turnover cum more rapid job creation and job destruction.

Finally, there is a strong possibility of welfare losses on the part of domestic producers,

but welfare gains among consumers due to lower prices are likely to be larger.

II.   The Import Discipline Hypothesis

Let us begin our discussion by recounting the logic behind the import discipline

hypothesis, and the firm-level evidence that is often cited in its support.

A.   Micro Foundations for the Trade-Efficiency Linkage

A variety of theoretical arguments provide possible explanations for the import

discipline hypothesis. Some of these apply to any policy reform that intensifies

competitive pressures. For example, in contexts where ownership is separate from

management, heightened competition can reduce agency problems, and thus may induce

managers to move toward high-effort contracts (Hart, 1983; Voustden and Campbell,

1994). This effect is quite sensitive to modeling assumptions, however, and might well go

in the other direction (Scharfstein, 1988; Martin, 1993).

Regardless of whether agency problems are present, competition may heighten

incentives to innovate among those firms close to the technological frontier, while

inducing the rest to forfeit market share and/or shut down. Boone (2000) defines

heightened competitive pressure as a shock that induces this pattern of response, and

provides some examples of demand systems and market equilibria that exhibit this

property.[1] Of course, competitive pressures may serve mainly to reduce the rents from

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[1]Aghion, *et al* (2003) develop a simple model with the same features. They posit that firms can improve
their efficiency by no more than one unit per period, so firms that lag more than one unit behind the

innovation, as Schumpeter argued, so these laudatory effects need not obtain. Aghion *et al* (2002) demonstrate that the relationship between product market competition and innovation might exhibit an inverted-U shape, reflecting the relative strength of Schumpeterian and Boone-type forces.

Other linkages between openness and efficiency are inherently trade-related. For example, Melitz (forthcoming) and Bernard *et al* (forthcoming) demonstrate that by liberalizing trade, countries create new markets for their most efficient firms and new competition for the rest. Thus it is possible to generate efficiency enhancing market share reallocations without necessarily involving innovative activity. Trade flows may also act as a conduit for embodied or disembodied knowledge flows, and may (or may not) change the returns to innovation through general equilibrium effects on factor prices and market sizes (Grossman and Helpman, 1991).

B.   The existing evidence

Given the widespread appeal of import discipline arguments, and given the many possible forms they might take, the profession has looked to empiricists to document their nature and measure their importance. Two developments during the past quarter-century have made it possible for the empiricists to respond in force. One is that numerous plant and firm-level data sets have accumulated over sufficient time spans to support econometric inference. The other is that many developing countries have dramatically liberalized their trade regimes, generating a number of natural experiments.

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technological frontier have no chance of catching up. With homogeneous products and Bertrand competition, the threat of competition from an efficient foreign supplier induces firms one step behind to invest in innovations, and induces those further back to relinquish their market.

At least five such natural experiments have attracted attention from empiricists. One of the earliest occurred in Chile, which went from widespread quantitative restrictions and average effective protection rates over 100 percent in 1967 to virtually no quantitative restrictions and average effective protection rates of 15 percent by 1979 (Tybout, et al, 1991). Next, Mexico went from license coverage ratios of 91 percent and tariff-based effective protection rates of 31 percent in 1984 to license coverage ratios of 11 percent and effective protection rates of 9 percent in 1990 (Tybout and Westbrook, 1995). The Cote d'Ivoire also began its liberalization in 1985, removing quantitative restrictions, and reducing average tariffs by 30 percent over the following 2 years (Harrison, 1994). More recently, Brazil reduced its exchange rate-adjusted average nominal tariff rate from 80 percent in 1985 to 21 percent in 1995, simultaneously eliminating non-tariff barriers (Muendler, 2003). Finally, in 1991 India removed "licensing and other non-tariff barriers on all imports of intermediate and capital goods and [implemented] significant reductions in tariffs on imports" (Krishna and Mitra, 1998).

Table 1 summarizes a subset of the resulting studies, grouped by country-specific liberalization episode. For each episode, we summarize evidence on plant- or firm-level productivity gains and their relation to measures of trade protection (column 4). Further, since productivity gains due to intra-plant innovations are conceptually distinct from those due to market share reallocations (including entry and exit), we cite evidence that isolates reallocation effects when it is available (column 5). Finally, to give some indication of whether competitive pressures intensified with trade liberalization, we cite studies that relate price-cost mark-ups to openness proxies in column 6.

The message that emerges from Table 1 is consistently supportive of the import discipline hypothesis. Import-competing sectors generally undergo the biggest productivity gains during and immediately after trade liberalization episodes. These gains are due, in significant part, to reallocation effects. And they are generally accompanied by reductions in price-cost mark-ups, suggesting that heightened competitive pressure is the driving force behind the adjustments.

C.   Limitations of the existing evidence

Taken together, the studies in Table 1 constitute a valuable set of stylized facts concerning the effects of trade policy on industrial sector performance. Nonetheless, our ability to draw policy implications from this evidence is limited by problems with the performance measures that have been used, and by problems linking these measures to the policy regime. We now consider each in turn.

Problems measuring performance

One measurement problem derives from data limitations. It is infeasible to collect detailed information on the quantities of each of the different product varieties that firms produce. Thus all of the productivity studies in Table 1 measure output as deflated revenues. Similarly, although most of these studies measure labor inputs in terms of number of workers or hours worked, data limitations force them to measure intermediate inputs as deflated expenditures, and capital stocks as depreciated and depreciated expenditures. The resulting productivity measures therefore fall somewhere between revenue per unit cost, and revenue per unit input bundle.

This feature of productivity measures would be a non-issue if outputs and intermediate input bundles were homogeneous across producers. But manufactured

6

products are quite differentiated, even within narrowly defined industries, and price-cost

mark-ups exhibit considerable variation across producers with product-specific demand

conditions. In this setting, Katayama, et al (2003, hereafter KLT) note that firms with

high mark-ups tend to generate lots of revenue per unit input bundle, and thus tend to

appear relatively productive. Similarly, high ratios of revenues to measured input usage

tend to occur at firms that pay dearly for their workers, since these firms pass some of

their labor costs forward to consumers. In contrast, when demand elasticities are

common across firms, cross sectional variation in true productive efficiency has little to

do with cross sectional variation in revenue per unit input bundle. The reason is that

productivity shocks cause input usage and revenue to move up or down roughly in

proportion to one another.[2]

This spurious cross-sectional variation in measured productivity matters

especially in studies where the effects of reallocation-based productivity gains are

calculated because big firms tend to pay their workers more, and to face relatively low

demand elasticities.[3] Thus they tend to look relatively efficient, even if their true

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[2] KLT show that if the production technology is constant returns and Cobb-Douglas, measured productivity
for the ith producer takes the form: $\tilde{\phi}_{it} = \mu_{it} + \ln \frac{\overline{W}_t}{\overline{P}_t} + \alpha \ln \frac{W_{it}^p}{\overline{W}_t^p}$, where μ_{it} is the firm's optimal mark-up
(determined by demand elasticities), $\overline{W}_t$ is the industry-wide price deflator used for factor inputs, $\overline{P}_t$ is the
industry-wide deflator used for sales revenues, $\overline{W}_t^p$ is the appropriate industry-wide price index for factors
measured in physical terms (most importantly, labor), W_{it}^p is the unobservable firm-specific unit price for
these same factors , and α is the share of total cost attribute to labor. Thus $\tilde{\phi}$ reflects mark-ups and
relative labor costs but it is independent of true productivity unless productivity affects mark-ups or the
prices of factors measured in physical units. Even if the workers are paid more because they are more
productive, the standard performance measures tell us nothing about economic efficiency because firms
that use valuable inputs to produce valuable outputs need not be more efficient than firms that use cheap
inputs to produce cheap output.

[3] Although it is somewhat tangential to our discussion, it is worth noting that this property of standard
productivity measures probably also creates large biases in studies that compare productivity indices across
multinationals, exporters and domestic producers.

7

productivity is mediocre, and measured efficiency gains will be overstated when market shares shift in favor of these firms. Nonetheless, to the extent that big firms get big by being efficient, one can expect *some* cross-sectional correlation between measured efficiency and true efficiency, so measures of reallocation-based productivity gains are not entirely spurious.

Time series variation in measured productivity is also likely to have a spurious component, albeit here again it should at least be correlated with true productivity growth. More precisely, if the cross-firm distribution of factor prices were time invariant, if the price deflators used were representative of the prices faced by the sample of producers being analyzed, and if firms could change their input usage without incurring adjustment costs, the *average* productivity measure would be a good proxy for average true productivity.[4] But mark-ups clearly tend fall with trade liberalization and this effect is particularly marked among large producers (Table 1, column 6). Thus, to the extent that this margin squeeze is most dramatic among import-competing firms, these studies may tend to *understate* efficiency gains in the import-competing industries during liberalization episodes. Measured productivity growth may also be understated in these industries because adjustment costs induce them to retain excess labor and capital during periods of slack demand. Both effects may help explain why the measured efficiency gains during the Brazilian, Chilean and the Mexico trade liberalizations were quite

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[4] Under the assumptions in footnote 1, this follows because profit maximization implies that the optimal mark-up (μ_{it}) is related to the firm's true productivity (ϕ_{it}) by $\mu_{it} = \phi_{it} - \ln\dfrac{W_{it}}{P_{it}}$, where $\ln W_{it}$ is the log of the unobservable firm-specific deflator for a unit bundle of all inputs, regardless of whether they are measured in physical or expenditure terms. Substituting this expression into the expression for measured productivity in footnote 1 and averaging across firms yields the result that cross-firm mean values of measured productivities should be close to mean values of true productivity if the price deflators used are representative of the sample of firms.

modest, despite major policy shocks and, at least in Chile, evidence of widespread labor shedding.

The fact that manufactured products are differentiated across firms and through time creates another basic measurement problem for the studies in Table 1. Product innovations generally affect social welfare, but productivity studies only pick up temporal variation in *process* innovation. Thus, for example, firms that save on input usage by producing less appealing products are likely to look better than firms that keep their marginal costs constant but improve their products. With variation in both product quality and productive efficiency, firms' performances should be measured in terms of their contributions to social surplus. Like the first problem, this one may be more important for cross-plant analyses than for time series, although changes in the set of available products probably matter over medium to long-term horizons.

A final measurement problem is that the Table 1 studies tend to miss some costs that firms incur in order to become more productive. Because the data are usually unavailable, analysts are usually unable to include investments in R&D, worker training and other types of overhead in their studies. Similarly, when efficiency gains are accomplished through labor shedding, severance costs and the costs borne by displaced workers are generally not part of the calculations. By understating the costs of innovation and workforce downsizing, the typical study tends to treat productivity gains as unequivocally desirable, and may overstate the gains from import competition.

Problems linking performance to the policy regime

Even if firms' performances had been appropriately measured, they would still leave some basic policy issues unresolved. One reason is that they are not very

informative about the underlying behavior that generated the observed patterns of association between performance measures and openness proxies. For example, although we can be fairly confident that intra-firm efficiency is correlated through time with openness, we don't know whether it reflects the changing nature of an agency problem, a shift in the return to innovation at owner-managed firms, or greater incentives to shed non-essential labor. Nor do we know whether trade liberalization increases the incentives to absorb new embodied technologies through capital investments.[5] Answers to these questions determine whether the observed correlations are due to domestic market failures—in which case trade policy may not be the best way to address them—or are inherently trade-related.

Related issues arise in studies that measure reallocation-based productivity gains. Most simply report the amount of sectoral productivity growth that is not attributable to intra-plant productivity gains (Pacvnik, 2001; Liu, 1993; Tybout and Westbrook, 1995; Tybout, 1992). But without a dynamic structural model to interpret these figures, it is impossible to say how things might have differed under a more protectionist regime.[6] Do reallocation-based gains reflect an improvement in the efficiency of the weeding out process, or are they present because liberalization creates more plants that *need* weeding out—perhaps by reducing the incentives to innovate?

Finally, because the time periods covered by the studies in Table 1 are relatively brief, it is not clear whether this body of evidence describes transitory changes or long-run adjustments. They might reflect a one-time shakedown, or they might reflect a lasting

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[5] Muendler (2003) does provide some evidence on the role of imported technologies in Brazil.

change in industry dynamics. They might even describe short-run effects that are more than reversed over the medium to long term.

III.   Interpreting the evidence with structural models

Thus far we have argued that the existing empirical evidence on import discipline effects is noisy and biased, but three basic findings are probably qualitatively correct. Specifically, among import-competing firms, trade liberalization squeezes price-cost margins, induces some intra-plant efficiency gains, and induces additional efficiency gains due to the shutting down of weak plants. We have also argued that, measurement issues aside, these findings are of limited use for policy analysis. They do not tell us anything about the managerial behavior behind the intra-plant productivity gains, they do not go beyond short-run effects, and they do not link adjustment patterns to welfare. The remainder of this paper presents a calibrated model that does all of these things in a way that is consistent with the empirical evidence.

A.   An Industrial Evolution Model with Import Discipline Effects

If we are to interpret the existing evidence and draw policy implications, we require a structural model that captures several basic features. First, if we are to study intra-firm productivity change, the model should include the micro foundations for at least one form of induced innovation. Second, given that we believe the trade regime affects competitive pressures and mark-ups, the model should allow for imperfect competition. Third, if we are to study adjustment paths, the model should be explicitly

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[6] Muendler (2003) goes one step further by estimating exit probabilities for incumbent plants before versus after the Brazilian trade liberalization of the early 1990s. But this exercise does not explain entry or market

dynamic, with forward-looking heterogeneous agents who foresee the future imperfectly.

Fourth, given that we believe turnover-based productivity growth is significant, the

model should allow for endogenous entry and market share reallocations. And finally, if

we are to study the *net* welfare effects of changes in behavior, the model should assign

some costs to entry and innovation.

Needless to say, the modeling exercise we have described above is a difficult one.

But if we forego econometric analysis and content ourselves with calibration, it *is*

possible to construct a computable model with all of these features, and thereby to

develop a broad sense for some of the dynamic structural relationships that are consistent

with the stylized facts of Table 1. In the remainder of this section we demonstrate how

this might be done, and we use the results to inform our interpretation of the econometric

evidence. To keep the analysis tractable we study a hypothetical industry populated by a

handful of firms that differ only in terms of the quality of their products.

The Ericson-Pakes-McGuire Model

We base our analysis closely on the industrial evolution model developed by

Ericson and Pakes (1995) and simulated by Pakes and McGuire (1994 and 2001). The

basic assumptions behind the simulated version of this model are concisely summarized

in Pakes (2001) and Pakes and McGuire (2001), which we now paraphrase.

The PEM model describes the evolution of an industry populated by a changing

set of firms, each producing a single differentiated product. Factor prices and the price of

an outside good—for present purposes, a composite imported good—are exogenous.

Product quality varies across firms and through time. The current-period pay-off to an

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share reallocations, and it fails to identify the deep parameters needed for counter-factual analysis.

active firm with product quality level i is determined by a profit function $\pi(i,s)$, where

$i \in Z^+$, the set of positive integers, and $s = \left[s_j ; j \in Z^+ \right]$ is a vector whose j^{th} element

gives the number of active firms at quality level j.[7] Given s, incumbents with product

quality i decide whether to remain active or exit and sell their firm for a scrap value ϕ.

Those that remain active also choose an investment level x, which costs them cx and

shifts the probability distribution for their next-period quality realization. Larger x

investments lead to more favorable shifts.

For a firm currently at quality i, investing x in product development, and

operating in a market with structure s, let $p(i',s' \mid x,i,s)$ be the perceived probability

distribution for next period's market structure. Then, given a discount factor of β, such a

firm perceives its current value to be

$$V(i,s) = \max\left\{ \phi, \ \pi(i,s) + \sup_{x \geq 0} \left[-cx + \beta \sum_{i',s'} V(i',s') p(i',s' \mid x,i,s) \right] \right\}. \quad (1)$$

If the max operator returns ϕ, it is optimal for the entrepreneur to sell the firm for scrap,

otherwise it chooses the investment level x that maximizes the term in square brackets

and proceeds to compete in the product market.

It is convenient to treat the quality index i as normalized relative to current quality

of the imported good. Then if i grows through time, firms at this quality level must be

investing more than enough in innovation to keep up with the quality of the imported good.

More precisely, let the Bernoulli random variables v_t and ζ_t represent increments to own

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[7] Given investment decisions, future realizations on (i,s) are presumed not to depend upon firms' current pricing or output decisions. Thus the profit function reflects a simple "spot market" equilibrium in the goods markets and, for example, punishment strategies are disallowed.

and foreign quality, respectively, and assume that i_t evolves according to:

$i_{t+1} - i_t = v_t - \zeta_t$. Shocks to the quality of the imported good, ζ_t, are exogenous draws

that take on the value one with probability $\mu(1) = \delta$, where $0 < \delta < 1$ is a constant. Shocks

to the quality of a domestic good depend upon the firm's investment current investment:

$P[v_t = 1 \mid x_t] = \dfrac{ax_t}{ax_t + 1}$, where $a > 0$ is a constant. Thus for a firm investing x_t, the

expected gain in quality relative to the imported good is $E(i_{t+1} - i_t) = \dfrac{ax_t}{ax_t + 1} - \delta$.

To further characterize the transition kernel, $p(i', s' \mid x, i, s)$, let $\hat{s}_i$ describes the

states of the competitors of a firm at state i when the industry structure is s, and let

$q(\hat{s}_i \mid i, s, \zeta)$ describes this firm's beliefs about the probability of landing at market

structure $\hat{s}_i$ next period, given the current state and ζ_t. Then the transition probabilities

that enter the value function (1) are:

$$p(i' = i*, s' = s* \mid x, i, s) = \sum_{\zeta} p(v = i* - i - \zeta \mid x) q(\hat{s}_i' = s* - e(i*) \mid i, s, \zeta) \mu(\zeta),$$

where $e(i)$ is a compatible vector with zeros everywhere except in the ith position, which

holds a one. Note that $q(\hat{s}_i \mid i, s, \zeta)$ embodies firm i's beliefs about entry behavior and the

value functions of all competing incumbents.

Finally, there is at most one entrant per period, and this entrepreneur creates a

firm if doing so generates an expected discounted cash flow that exceeds the entry cost,

x_e. Any potential entrant for whom this condition holds pays x_e (drawn from a uniform

distribution), and after a set-up period becomes an incumbent with an initial relative

quality i^e. Note that i^e measures quality relative to imported good, so this specification

means that entrants always jump into the market the same expected distance from the foreign best practice frontier, so it amounts to the assumption that foreign technological innovations are always embodied in the capital stocks of new firms, up to a constant gap.

Equilibria obtain when all firms' beliefs, $q(\hat{s}_i \mid i, s, \zeta)$, are consistent with the objective distribution of industry structures based on the investment, entry and exit rules described above. Pakes and Erikson (1995) show that Markov-perfect equilibria exist, although uniqueness is not ensured. Also, although the industry exhibits ongoing entry and exit, the number of firms is bounded by some integer $\bar{n}$, and each active firm is limited to a finite integer set of states, $\Omega = \{1, \ldots, K\}$. Thus one need only compute equilibria for tuples $(i, s) \in \Omega \times S$ where $S \equiv \left\{ s = [s_1, \ldots, s_k] : \sum_j s_j \leq \bar{n} < \infty \right\}$.

Our adaptation of the model

We base firms' profit functions on pure Bertrand competition in product markets characterized by a nested-logit demand system (McFadden, 1974). Nest 0 contains only the composite imported variety, and nest 1 contains all of the domestic varieties. More precisely, we define the net utility that the jth consumer derives from consuming a unit of product i at price P_{it} in period t to be:

$$U_{ijt} = \begin{cases} \omega_{0t} + \omega_{it} - \theta P_{it} + \xi_{j,1t} + (1-\varphi)\varepsilon_{ijt} & i = 1, N_t \\ \omega_{0t} - \theta P_{0t} + \xi_{j,0t} + (1-\varphi)\varepsilon_{0jt} & i = 0 \end{cases} .$$

Here P_{0t} is the price of the imported good, $\omega_{0t} = g\left(\sum_{k=1}^{t} \zeta_k \right)$, $g'(\cdot) \geq 0$, $g''(\cdot) < 0$, measures the mean gross utility delivered by a unit of the current generation imported

variety, and $\omega_{it} = f(i_t)$ measures the mean *extra* utility delivered by a unit of any

domestic good at quality level i_t.[8] Also, $\theta > 0$ measures price sensitivity, and φ

measures the degree of substitution between domestic varieties and the imported good

($0 < \varphi < 1$). The latter follows because $\xi_{j,dt}$ varies only across individuals and across

nests (d=1 for domestic varieties and 0 for imports), while ε_{ijt} varies across individuals

and across *all* varieties. (Both $\xi_{j,dt} + (1-\varphi)\varepsilon_{ijt}$ and ε_{ij} have extreme value distributions

across individuals.) This allows us to control the degree of substitution between imports

and the domestic varieties.[9]

Given our utility function, improvements in the quality of the imported good and

reductions in its price have very similar effects from the perspective of consumers. Thus

ongoing quality improvements abroad can also be viewed as ongoing price reductions,

perhaps due to exchange rate appreciation. Similar comments apply concerning the

domestic goods. Marginal cost reductions always lead to price reductions in our

characterization of the spot market equilibrium. So, although we assume that the

domestic firms have identical, flat marginal cost schedules, roughly speaking we may

view the effects of product innovations as similar to the effects of process innovation.

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[8] We use $f(i) = 15i/(i+1) - 5$. (We do not need to make specific assumptions about $g(\cdot)$ to solve the model, since it only affects the level of consumer surplus.) Note that our specification for $f(\cdot)$ implies diminishing marginal utility from quality premiums. Also, it ensures that the return to quality improvements (relative to the imported good) approaches zero as $i \to \infty$, and thus eliminates the incentive for firms to drive i above the maximum value considered, K.

[9] Berry (1994) provides further details on the product market equilibria that obtain with nested logit demands and pure Bertrand pricing rules.

B. The Simulation Exercises

Using modified versions of the Gauss and C programs written by Ariel Pakes, Paul McGuire and Gautam Gowrisankaran, we study the effects of import competition on industrial structure using two policy experiments. The first is to permanently reduce the price of the composite imported good, P_0 (hereafter, the "RPM experiment"). It is meant to approximate a reduction in trade barriers. The second is to permanently accelerate the rate of innovation for imported goods, δ (hereafter, the AIM experiment). It is meant to describe the effects of trading with a country where technological progress is rapid, as opposed to modest.

Both sets of exercises begin from a parameterization in which imports have a very small market share. Also, we assume that no more than six domestic firms are simultaneously active in the domestic market. (This bound is rarely hit under the parameterizations we use—three to five firms are typically active.) Thus we caution that the results may overstate the importance of oligopolistic interactions for most manufacturing industries.

To eliminate any role for starting values, we begin each simulation with 5,000 periods under the pre-reform parameterization, then we shock the parameter of interest and track the industry's adjustment. The shock is always presumed to surprise entrepreneurs, but once in place the new parameter values are presumed to be common knowledge. Each experiment is repeated 100 times, and the average trajectories are graphed. Our graphs are normalized so that the regime change takes place in period 50, and thereafter they show both the simulated responses and the mean trajectory that would

have emerged in the absence of the regime switch. The parameter values we use for these simulations are presented in Table 2.

It is not possible to be precise about the length of time that corresponds to a single period. But the typical life span of a firm in our simulations is 4 to 6 periods, so an average life span of 10 years implies that one period amounts to roughly 2 years. Similarly, we note that the average entry/exit rate in our base case simulations is 23 percent, which is roughly twice the annual rate observed among manufacturing plants in semi-industrialized countries (Roberts and Tybout, 1996).

Reduced Price for Imports (RPM)

Our results for a permanent reduction in the price of imports—the RPM experiment—are summarized by figures 1.1 through 1.8 and the first two columns of Table 3. Consider first the domestic market share trajectories presented in figure 1.1. When the price of the imported good drops from 1.5 to 0, the share of output supplied by domestic firms immediately drops as consumers shift toward the import variety. The price-cost mark-ups of domestic varieties also drop as domestic entrepreneurs react to the new environment (figure 1.5).

The net exit rate is roughly 10 percent in the first post-reform period, and all of the disappearing firms come from the low end of the product quality distribution. Thus the unweighted average quality of domestic goods rises sharply in the immediate aftermath of the reform (figure 1.2). (The *weighted* average relative quality of domestic goods doesn't change much initially because exiting firms are small—see figure 1.3.) But incentives to innovate are clearly less at the lower imported price, reflecting a simple Schumpeterian mechanism: firms with the most market power gain the most from R&D

(figure 1.4).[10] Consequently, average quality/efficiency begins a sustained downward trend after 4 or 5 periods. One implication is that short-run analyses of the efficiency effects of trade liberalization may be quite misleading.

Workers are unlikely to like the new regime because it discourages investments in product improvements, thereby reducing firms' average live spans (Table 3) and increasing rates of job turnover. On the other hand, consumers are clearly better off, especially during the early periods (figure 1.8). This is because the prices of domestic and foreign goods are lower after the reform (figure 1.5), the decline in the relative quality of domestic goods hasn't really gotten started (figures 1.2 and 1.3), and the domestic varieties that exit weren't contributing much to their welfare. Consumers' enthusiasm for the new regime fades as the relative quality of domestic products declines, and the prices of these goods come back up a bit. But overall, the reform generates a 22 percent increase in the present value of their surplus (Table 3).[11]

Finally, domestic producers suffer capital losses when the regime hits, and they remain worse off under the new regime because their mark-ups are smaller (figure 1.7). Overall, the present value of their surplus is reduced by 11 percent. Nonetheless, social welfare is dominated by consumer surplus, which increases in present value by 21 percent (Table 3).

Of course, other assumptions might have led to different patterns of response, and we could certainly refine our calibration, but it is noteworthy that our simulations match

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[10] Rodrik (1992) flags this effect as a possible reaction to heightened import competition. In our model it is conceivable that a small reduction in the price of imports might drive a marginal firm from the market, thereby increasing the return to innovation for the remaining producers. However, this phenomenon is clearly not typical of our simulations.

up well to most of the econometric evidence. That is, import competition induces smaller firms, lower mark-ups, and a cleansing effect that helps to sustain efficiency. The only seeming incongruity is that efficiency gains in the RPM experiment come exclusively from firm turnover and market share reallocations in our simulations, while the studies in Table 1 find significant intra-firm productivity gains. However, one can reconcile this experiment with the evidence by simply thinking of entry and exit as corresponding to product lines rather than plants. Then the same plant might continue to exist as it retools for a new product, and thus might exhibit short run intra-plant efficiency gains. This interpretation is consistent with evidence on the Chilean experience, where plants improved their efficiency by shedding labor rather than expanding output with a given labor force (e.g., Tybout, 1996). It is also consistent with the common finding that, while manufacturing productivity improves after trade liberalization, unemployment increases economy-wide, and therefore aggregate productivity growth is modest.

Accelerated innovation among imports (AIM)

An alternative form of opening occurs when domestic firms are faced with accelerated innovation among the imported goods. We think of this type of shock as approximating policies that bring dynamic new trading partners into play and/or policies that remove non-tariff barriers on products that are subject to relatively rapid technological change. It might also approximate policies that lead to extended periods of real exchange rate appreciation, although it is difficult to imagine this occurring indefinitely without macro crises emerging. The simulated responses to such a regime change are graphed in figures 2.1 through 2.8, which contrast behavior when $\delta = 0.6$ with

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[11] Given that we have held the rate of innovation among imported goods fixed, consumer preferences for the open regime don't depend upon what functional form we choose for $g(\cdot)$.

behavior when $\delta =0.8$. (Recall that δ is the exogenous probability of an improvement in the quality of imported goods.)

Figure 2.1 shows that domestic firms lose no market share in the face of this type of competitive pressure. The reason is that they reduce their prices enough to compensate for the reduction in their relative quality once new regime begins to take hold (figure 2.5). They do, however, gradually lose relative quality (figures 2.2 and 2.3, lower line) as improvements among imported goods cumulate and they increasingly scale back their own investments (figure 2.4). The gradual decline in domestic investment mirrors the gradual fall in domestic mark-ups, once again reflecting a Shumpeterian reduction in the incentive to innovate.

Our post-reform series on relative efficiency are a bit misleading because, when the rate of innovation among imported goods increases, the yardstick for performance of the domestic varieties increases too. Thereafter domestic producers must improve their quality index by 0.8 per period rather than 0.6 per period simply in order to keep up. So although relative quality trends downward for 40 periods after the AIM regime is implemented, the per-period change in the *level* of domestic quality actually increases. We demonstrate this with an extra trajectory in figures 2.2 and 2.3 (top line) that shows the quality of the domestic goods relative to a hypothetical reference good that continues to improve by 0.6 per period after the reform is implemented. This scenario is therefore consistent with the stylized fact that *intra*-firm efficiency gains accelerate after liberalization episodes.

That domestic producers are able to increase the rate of improvement in their goods reflects two forces. First, the mean life span of firms drops 23 percent when δ

increases from 0.6 to 0.8 (Table 3). Second, after the regime switch, new firms are able to embody rapidly improving global best practice technologies in their plants at no additional expense. Thus, although firms invest less in keeping up with import innovations, each is more quickly replaced by an entrant near the technology frontier.[12] This type of induced innovation provides some micro foundations for the common finding that countries with high-tech trading partners enjoy relatively rapid growth (Coe and Helpman, 1995).

The AIM shock immediately improves producer surplus because domestic firms don't lose much relative quality initially, and they spend less of their gross revenue on investment (figure 2.7). However, the cost savings from reduced investments are gradually swamped by the revenue losses induced by persistently higher rates of quality improvements among imports.

How do consumers fare? Figure 2.8 suggests that they to do worse than they did under the RPM experiment because the relative quality of imported goods has fallen. However, this figure is drawn under the extreme assumption that consumers only care about the variety of goods available and their *relative* quality, and not about the average *level* of quality. (That is, $g'(\omega_{0t}) = 0$.) If we had allowed $g(\omega_{0t})$ to grow with improvements in the quality of imports, we could easily have demonstrated large consumer gains due to the more rapid rate of quality improvement among both domestic and imported goods. The interested reader may choose his favorite $g(\ )$ specification and perform this exercise for himself.

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[12] If new firms were allowed to endogenously invest in order to influence their initial product quality, the AIM shock would increase entrants' initial investments and thus increase their relative size. That is, given the choice, entrepreneurs adjust by shifting their investments away from post-entry expenditures toward

IV. Summary and Conclusions

The existing literature on industrial responses to trade liberalization documents consistent patterns of correlation between openness proxies and several measures of performance: price-cost mark-ups, intra-plant productivity gains, and reallocation-based productivity gains. These stylized facts are useful, but they don't tell us much about the underlying behavior of producers, nor do they link firms' performances to welfare measures, so they are of limited use for policy analysis. We have sketched an alternative approach to the analysis of trade liberalization that does both, and we have demonstrated this approach using fabricated data.

Lessons from the simulation exercises

Although our simulations are not calibrated to actual data, they make several basic points. First, when outward-oriented trade reforms reduce price-cost mark-ups, the less successful producers are likely to shut down or eliminate some product lines. This one-time adjustment in the set of firms and products is a quick source of efficiency gains, particularly when the new policy regime involves a sudden, significant departure from the previous environment. But it dissipates after 5 or 6 periods (10 to 12 years). Thus panel-based econometric studies of liberalization-based productivity gains—which typically span a decade, or less—are probably not representative of longer term effects.

Second, the same forces that induce exit tend to discourage innovation, so after liberalization, the quality of domestic products may well decline relative to imports. This

pre-entry expenditures. Experiments that demonstrate this reaction are available from the authors upon request.

effect is gradual, but in our simulations it eventually swamps the efficiency-enhancing effects of the initial wave of exits. In principle, other characterizations of market equilibria might have led to different conclusions concerning the effects of foreign competition on domestic innovation—Boone (2000) and Aghion *et al* (2002) provide some examples. But we found it difficult to identify plausible specifications that reverse this finding.

Third, falling behind in *relative* quality need not lead to deceleration in the absolute rate of innovation. Deceleration is less likely if trade liberalization increases the rate at which embodied technologies become available through capital goods imports. The more rapid these arrivals, the better new entrants are positioned to produce near the technological frontier.

Fourth, plant and job turnover rates are likely to be permanently higher after liberalization. This effect is particularly marked when the reforms allow new, embodied technologies arrive to arrive relatively rapidly through capital goods imports. Such an environment creates ongoing incentives to introduce new plants or assembly lines, rather than continually to upgrade existing facilities. The resultant higher turnover works to the detriment of labor, which is more frequently displaced.[13]

Fifth, although all of our figures represent averages over 100 trajectories, they still reflect a large role for idiosyncratic shocks. Thus the consequences of policy reforms may

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[13]Heightened foreign competition may have had this effect in India. A recent study of India's post-liberalization period finds that "firms subject to external exposure . . . face higher earnings variability and job insecurity. At the same time, though, the employees of foreign owned and import-competing firms are more frequently involved in training programs than firms not subject to foreign competition." (Daveri *et al*, 2002).. Similarly, Levinsohn (1999) finds that tradeable goods sectors exhibited relatively high job turnover rates in post-liberalization Chile.

remain obscured by noise for substantial periods of time, particularly when one is studying variables that respond to expectations like investment, entry and exit.

Future directions

There are at least two important limitations to the strategy we have demonstrated in this paper. The first is that it involves many modeling assumptions. We would naturally prefer to avoid using so much structure, but we do not believe it is possible to perform welfare-based policy analysis without it. Our view is: if the calibrated models generate patterns of turnover, pricing and efficiency gains that match observed patterns, they simply provide a coherent interpretation for observed experiences. One of our objectives is develop enough experience with computable industrial evolution models that we have a good sense for the practical importance of the various modeling assumptions.

The second limitation of our approach to analysis is that it is computationally intensive. The solution algorithms currently available for PEM models handle about a dozen firms, at most, and can take hours to solve for value functions at a given set of parameter values. Thus they can be calibrated to small industries using actual data on market shares, turnover patterns, prices and efficiency gains, but they are unlikely to serve as a basis for econometric estimation of all parameters. (Entry costs and scrap values are particularly difficult to identify.) We are currently exploring alternative solution algorithms that will allow us to handle more firms, and we are attempting to calibrate PEM-type models more tightly to actual liberalization experiences.

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Table 1: Openness, Mark-ups and Productivity Growth

Country and liberalization episode	Performance Measure	Performance Determinant	Intra-plant productivity growth	Entry, Exit and Market Share Reallocation	Mark-up Effects
Chile, 1973-79					
DeMelo and Urata (1986)	Price-cost margin	Import penetration rate			Post-reform penetration of imports reduced mark-ups most in highly concentrated sectors.
Tybout et al (1991)	Econometrically estimated TFP residuals	Effective protection rates	Sectors undergoing large reductions in protection exhibit the largest gains		
Tybout* (1996)	Price-cost margin	Import penetration rate			Margins are negatively affected by import penetration, especially among large plants.
Liu* (1993)	Econometrically estimated TFP residuals			Entry/exit a significant determinant of productivity growth	
Pavcnik* (2002)	Olley-Pakes (1996) estimates of TFP residuals	Tariff rates	Productivity grew faster in import-competing sectors with trade liberalization	Most of the post-liberalization productivity gains came from market share reallocations and entry/exit	

***Based on data from post-reform years only (1979-1986)

Country and liberalization episode	Performance Measure	Performance Determinant	Intra-plant productivity growth	Entry, Exit and Market Share Reallocation	Mark-up Effects
Brazil, 1991-94					
Muendler (2003)	Olley-Pakes (1996) estimates of TFP residuals	Tariff rates, market penetration rates	Import competition substantially increases productivity	Exit significantly contributed to efficiency gains; other forms of market share reallocation not studied	
Hay (2001)	Econometrically estimated TFP residuals; operating profits	Tariff rates, effective rates of protection, Exchange rate	Import competition increases productivity		Operating profits are positively associated with nominal protection rates.
Mexico, 1984-89					
Tybout and Westbrook (1995)	Production function-based TFP residuals	Effective protection, import penetration, license coverage ratios	Sectors with most exposure to import competition showed the most gain		
Grether (1996)	Price cost margin	Effective protection rates, official protection rates, license coverage rates			Big firms undergoing the most reduction in protection show the biggest reduction in margins
India, 1991-97					
Krishna and Mitra (1998)	Hall (1988)-type estimates of TFP residuals and mark-ups	Trade liberalization dummy	Productivity gains with trade liberalization		Significant reductions in mark-ups after trade liberalization
Cote d'Ivoire					
Harrison (1994)	Hall (1988)-type estimates of TFP residuals and mark-ups		Productivity growth tripled after trade liberalization		Weak evidence that price-cost margins fell with trade liberalization
Harrison (1996)	Production function-based TFP residuals; price-cost margins	Tariff rates, controlling for FDI in plants, sector	High tariffs are negatively associated with productivity, controlling for FDI		High tariffs are associated with high margins and low productivity.

Table 2: Parameter Values for Policy Experiments

Parameters	Reduced Price for Imports (RPM)	Accelerated Innovation for Imports (AIM)
Marginal costs of production (domestic firms)	1	1
Market Size (M)	10	10
Discount factor (β)	0.925	0.925
Scrap Value (ϕ)	0.1	0.1
Max Efficiency (i^{max})	21	21
Investment efficiency (a)	2	2
Price sensitivity of consumers (θ)	5	5
Degree of substitution between nests (σ)	0.5	0.5
Price of the imported good (P_0)	1.5 to 0	1.5
Probability of Innovation in the Imported good (δ)	0.6	0.6 to 0.8

Table 3: Summary Statistics for RPM and AIM regimes*

	Base case	Reduced Price for Imports (RPM)	Accelerated Import Innovation (AIM)
	P_0=1.5, $\delta = 0.6$	$P_0 = 0.0$, $\delta = 0.6$	P_0=1.5 $\delta = 0.8$
Percentage of periods with entry and exit*	55.8	57.8	72.1
Mean number of firms active*	3.8	3.6	2.9
Mean lifespan*	5.3	5.0	4.2
Mean consumer surplus**	855.3	1045.9	686.5***
Mean producer surplus**	27.9	25.0	30.1
Mean total surplus**	882.8	1072.0	716.6***

*   Means taken across 100 trajectories of 5,000 periods each
** Means taken across 100 trajectories of 100 periods each, discounted back to initial year of regime
***Excludes gains due to more rapid growth in the average quality of goods.

Figure 1.1:
Domestic Market Share, RPM Experiment
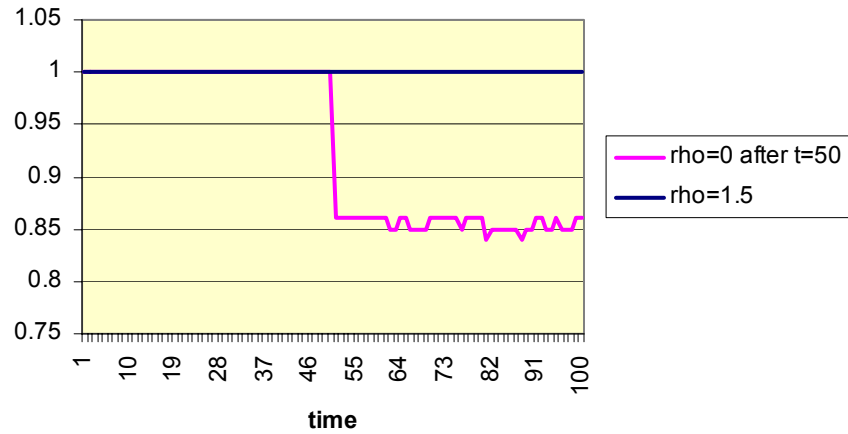
Figure 1.2:
Unweighted Mean Efficiency, RPM Experiment
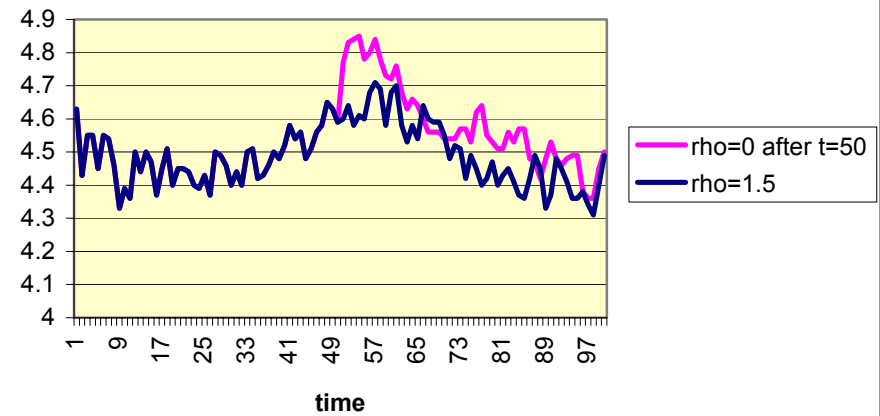
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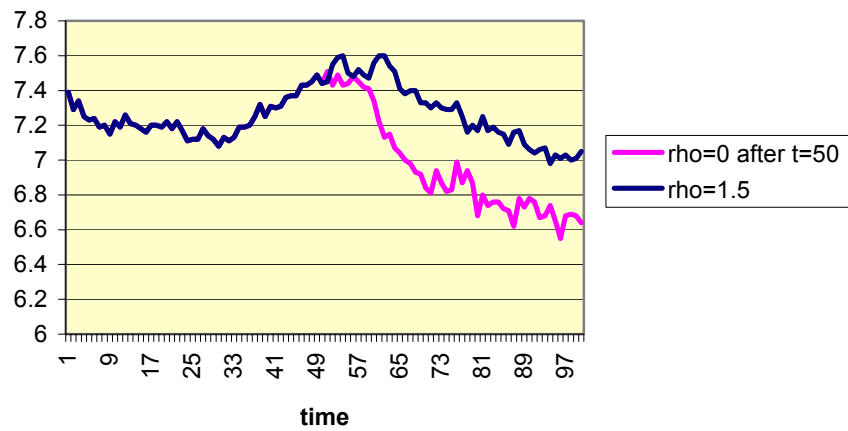
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Unweighted Mean Investment, RPM Experiment
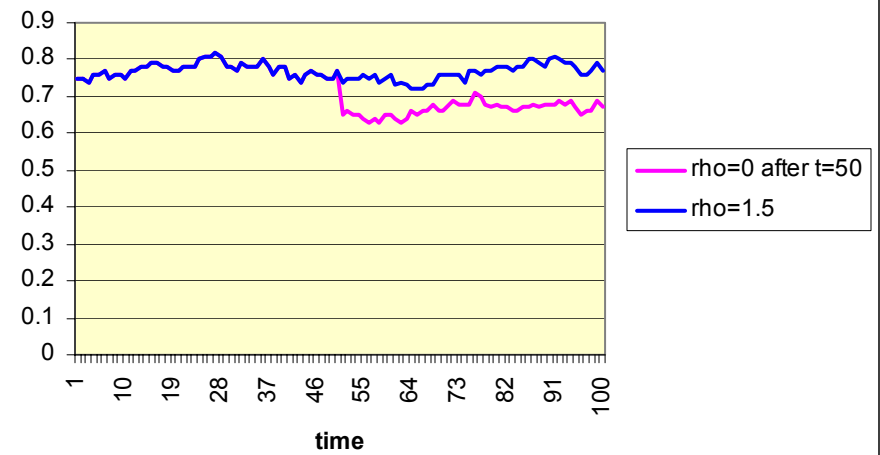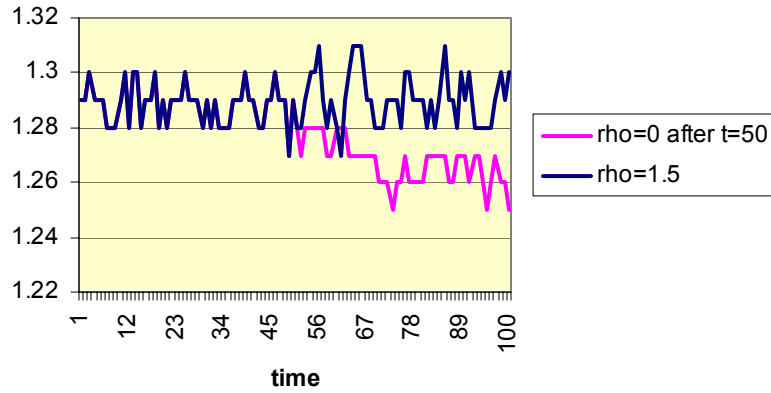
Figure 1.5:
Price-Cost Margin, RPM Experiment

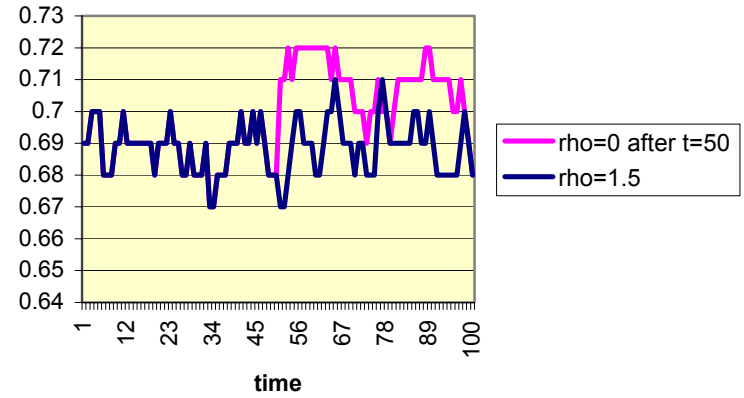**Figure 1.6:**
One Firm Concentration, RPM Experiment
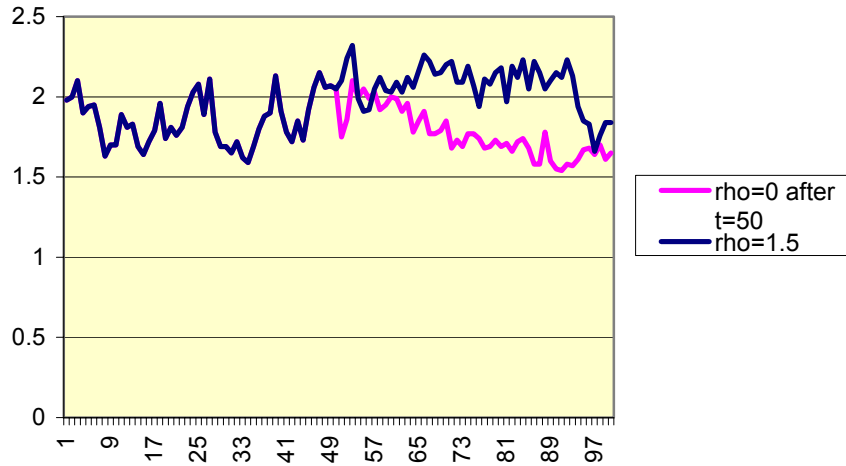
Figure 1.7:
Producer Surplus, RPM Experiment
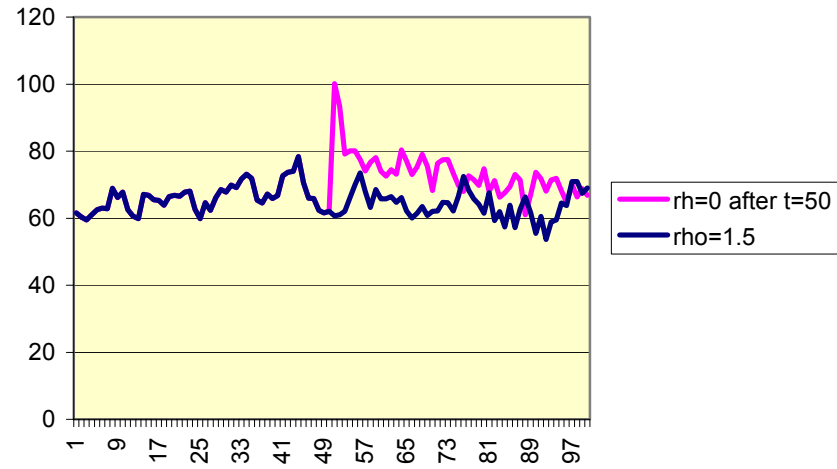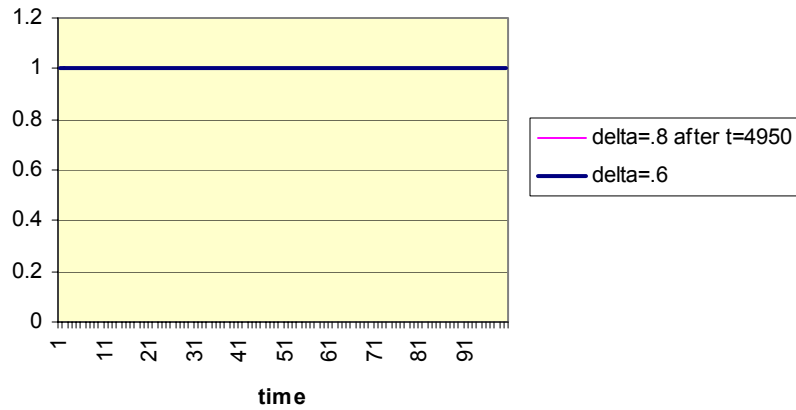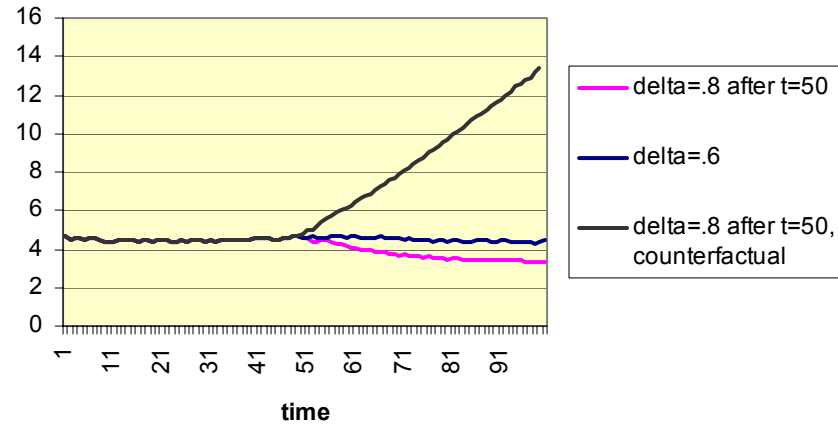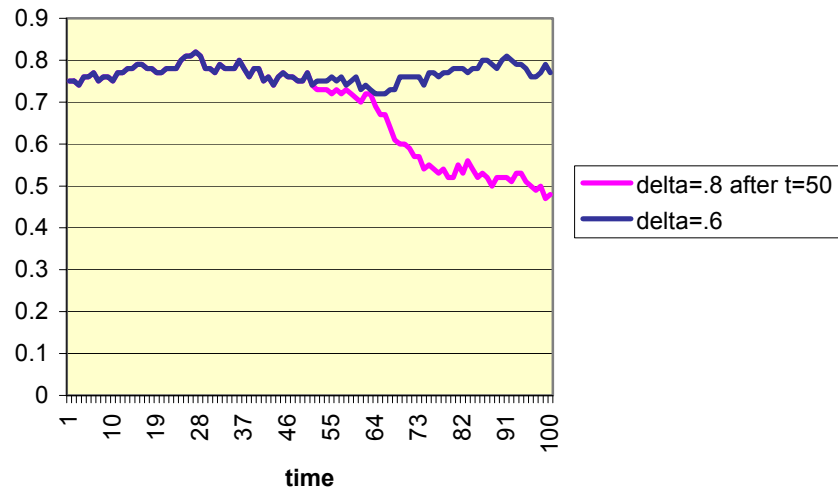
Figure 1.8:
Consumer Surplus, RPM Experiment

Figure 2.1:
Domestic Market Share, AIM Experiment

Figure 2.2:
Unweighted Mean Efficiency, AIM Experiment

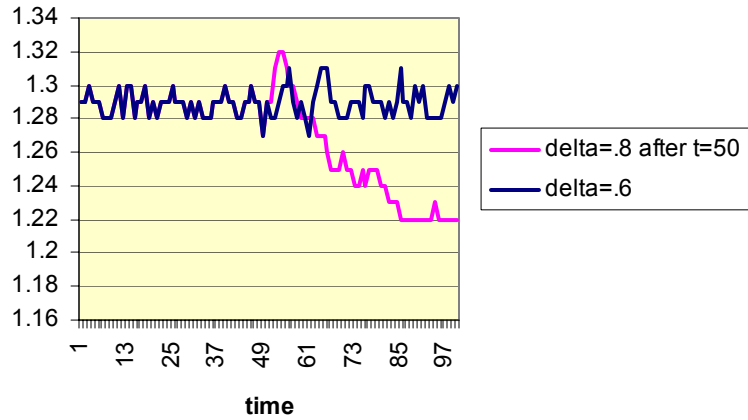**Figure 2.3:**
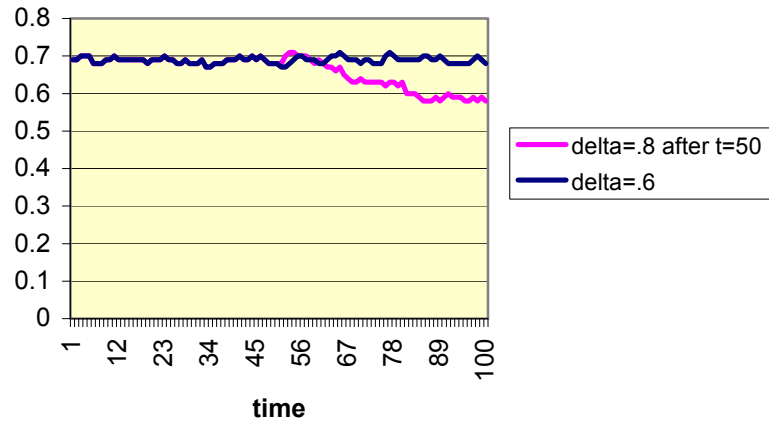**Weighted Mean Efficiency, AIM Experiment**
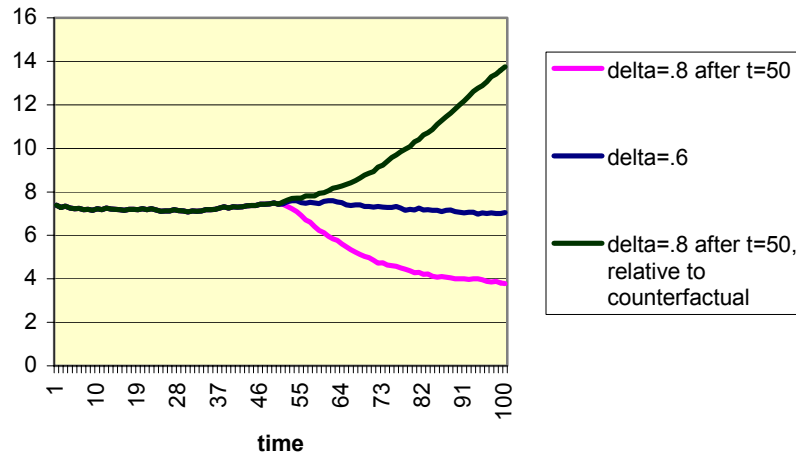
Figure 2.4:
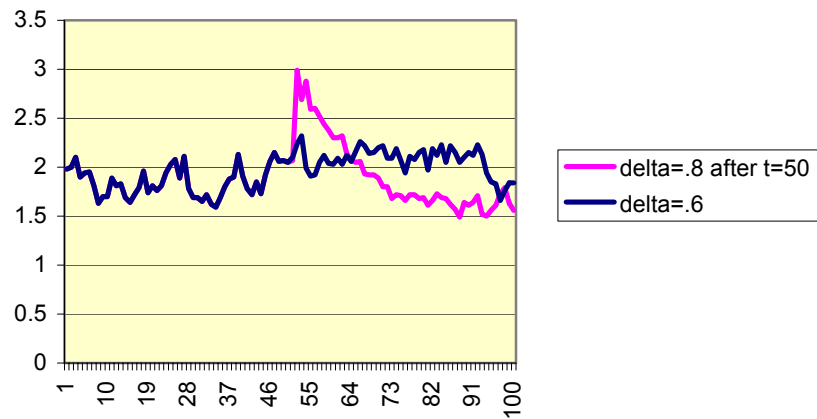**Unweighted Mean Investment, AIM Experiment**

34

Figure 2.5:
Price-Cost Margin, AIM Experiment

Figure 2.6:
One Firm Concentration, AIM Experiment

Figure 2.7:
Producer Surplus, AIM Experiment

Figure 2.8:
Consumer Surplus, AIM Experiment