Imported Inputs, Irreversibility, and International Trade Dynamics

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Abstract

In aggregate data, trade volumes adjust slowly in response to relative price changes, an observation at odds with standard theories. This paper develops a model of trade in intermediate inputs in which heterogeneous producers face a plant-level irreversibility in the structure of inputs used in production. Relative price movements induce immediate changes in aggregate imported relative to domestic purchases through adjustment within importing producers, and through the reallocation of resources between non-importing and importing producers. Additionally, trade volumes adjust slowly through gradual changes in the fraction of importers in the economy. When calibrated to match cross-section data on plant-level heterogeneity in imports, the model predicts magnitudes of these margins that are broadly in line with those in plant-level data.

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1 Introduction

Intermediate goods comprise the bulk of international merchandise trade for many of the world's industrial economies.[1] At the level of individual producers, there is substantial heterogeneity in the use of imported inputs: relatively few producers use imports, and those that do are larger and more productive than those that do not. For example, in both the US and Chile, only about one quarter of manufacturing plants use imported intermediate inputs. In addition, these importing plants are significantly larger, on average, than their non-importing counterparts.[2] These producer-level differences can have important consequences for the short-run fluctuations in aggregate trade volumes in response to shocks, as well as the long-run effects of trade liberalization on the volume of trade and welfare.

In aggregate trade data, imports relative to domestic purchases move slowly in response to changes in the relative price of imports. As a consequence, long-term growth in trade is much larger than the immediate response to a trade reform, so that the aggregate elasticity of substitution between imports and domestic inputs (the so-called Armington elasticity) is time-varying. In addition, using Chilean plant-level data, I document that a substantial portion of the fluctuations in aggregate trade flows at short to medium time horizons (one to five years) is accounted for by the reallocation of resources between plants that import and plants that do not, and by changes in the set of importing plants. Standard trade models with identical producers cannot account for these features of data on trade growth.

I develop a dynamic model in which heterogeneous plants choose whether to import some of their inputs. Importing expands the variety of imperfectly substitutable inputs used in production, as in the models of Ethier (1982) and Romer (1990), and so raises plant-level productivity, but involves paying an up-front sunk cost. The decision to import or not is partly irreversible. Each period, only a fraction of existing nonimporting plants have the opportunity to start importing. Plants receive idiosyncratic, persistent shocks to their inherent production efficiency, so only plants that receive a sufficiently high level of efficiency are profitable enough to cover the sunk cost to import. With plants separated according to whether they import or not, movements in aggregate trade flows in response to changes in the relative price of imports are shaped by four margins of adjustment. In response to a drop in the price of imports, first, importing plants purchase more imports relative to domestic goods; second, importing plants become more profitable, so they grow relative to nonimporting plants. To the extent that the import price is persistent, the third and fourth

[1]See Table 1 for details.

[2]See Kurz (2006) for the US, and Section 2 below and Kasahara and Lapham (2007) for Chile. Similar findings are reported in Amiti and Konings (2007) for Indonesia; Biscourp and Kramarz (2007) for France; and Halpern, Koren, and Szeidl (2009) for Hungary.

margins are that a higher fraction of previous nonimporting plants switch to importing, and a higher fraction of new entrants choose to import. All four channels contribute to an increase in the aggregate ratio of expenditures on imports to domestic goods. I refer to these margins of trade growth as the within-plant, between-plant, switching and net entry margins, respectively.

To quantify the aggregate implications of the plant-level importing decision, I calibrate the model to reproduce key cross-sectional moments in Chilean plant-level data, both with and without the switching friction. In the absence of this friction, all nonimporting plants are free to chose whether to start importing, subject to paying the fixed cost of switching. The findings show that introducing the friction is necessary. When subjected to short-run fluctuations in the relative price of imports of the magnitude observed in Chile over the period 1979-1996, the model with no switching friction generates a short-run Armington elasticity that is about 50 percent larger than in the Chilean data, and also substantially larger than estimates in the literature. In addition, the switching margin accounts for the majority of fluctuations in the import share, which is at odds with the plant-level data. This is because when the model is calibrated to the amount of switching that happens on average in the data, there are large fluctuations in the fraction of plants that switch in response to aggregate shocks. Introducing the switching friction, calibrated to one additional moment, improves these predictions. The aggregate short-run Armington elasticity is lower, and the switching contribution in the decomposition of import growth is reduced by half, although still larger than in the data. In response to a trade liberalization, both models generate a long-run Armington elasticity that is higher than the short-run elasticity, and the gradual nature of the growth in trade means this elasticity grows with the time horizon. The additional long-term growth in trade is due to the gradual adjustment of the fractions of existing plants that import, as well as from the decisions of new entrants, which accumulates over time. The switching friction further slows trade growth in response to a permanent price change relative to the model with no friction, since only a fraction of plants are able to make the decision to switch to importing each period.

The slow growth in trade following a permanent trade liberalization has important consequences for welfare: the accompanying slow growth of aggregate consumption reduces the welfare gains from a trade liberalization compared to a model in which all the growth is immediate. In my numerical experiments, the welfare gain from a reform that reduces the price of imports by five percent is about sixteen percent lower in my model than in a model that generates the same steady-state growth in trade with no transition.

This paper is related to recent work on dynamic models of producer-level exporting decisions. Ruhl (2008) also develops a model in which short-run and long-run responses of trade flows to relative price changes differ because plants face sunk costs of exporting, and hence, the Armington elasticity differs with the time horizon. This paper differs from Ruhl (2008) in the focus on importing decisions, but more importantly by incorporating idiosyncratic shocks to efficiency that generate switching even in the absence of aggregate fluctuations. This element is key to showing that a switching friction is needed to bring the model in line with the data. When the model with only sunk costs is calibrated so that the degree of plant-level switching in response to idiosyncratic shocks matches the average amount of switching in the data, the short-run response to aggregate shocks is too large, and features far too much switching between importing and nonimporting. In addition, the response to permanent price changes in my model takes into account transition dynamics that are not present in Ruhl (2008). Alessandria and Choi (2011) and Atkeson and Burstein (2010) also study the transition path following trade liberalization in models in which producer-level efficiency evolves over time. Alessandria, Pratap, and Yue (2012) analyze a model in which the stock of exporting plants moves slowly over time, and generates a time-varying Armington elasticity. Ghironi and Melitz (2005) and Alessandria and Choi (2007) develop dynamic models with fixed costs of exporting, but focus on the business cycle properties of these models.

The key assumptions behind the model's prediction that only few, large plants use imported inputs are that importing raises productivity and that importing involves a sunk cost. In addition, the partial irreversibility in the import decision implied by the switching friction is crucial for accounting for the plant-level decomposition. Studies estimating plant-level production functions find evidence that importing raises plant-level productivity, controlling for other sources of heterogeneity (for example, Kasahara and Rodrigue (2008); Halpern, Koren, and Szeidl (2009); and Goldberg, Khandelwal, Pavcnik, and Topalova (2010)). In my model, importing expands the variety of inputs used in production, which generates a productivity gain that depends on how substitutable inputs are in production, so the estimates of this productivity gain in the literature provide a check on the value of the elasticity of substitution at the plant level.[3] Given that there are gains to importing, then the fact that few plants use imported inputs suggests there are costs of doing so. Although there are no direct estimates of the fixed or sunk costs firms face to use imported inputs, I calibrate the sunk cost necessary to match the fraction of plants that choose to import in the Chilean data. Kasahara (2004) provides evidence of substantial irreversibility in the composition of

[3]There are alternative mechanisms by which importing may raise plant level productivity; for example, imports may be of higher quality than domestic inputs (see, e.g. Kugler and Verhoogen (2009)), or imports may provide close substitutes for domestic inputs at a cheaper price. Halpern, Koren, and Szeidl (2009) provide some evidence that increased variety from importing contributes more to the productivity gain from importing than higher quality for Hungarian plants.

intermediate inputs that plants use.[4]

The model in this paper is related to that in Kasahara and Lapham (2007), who consider both importing and exporting at the firm level. Their focus is on structural estimation of parameters that determine firm-level importing and exporting decisions in a stationary aggregate environment, while my focus is on quantifying the effects of heterogeneity in importing on the dynamics of aggregate trade flows in response to shocks. Also closely related is Gopinath and Neiman (2011), who develop a model in which shocks to the price of imports change both the number of firms importing and the number of goods each firm imports. They use transaction-level customs data for importing firms to quantify the importance of each of these margins for aggregate trade and welfare. The main difference in my paper is that I also examine the importance of the reallocation of resources between importing and nonimporting plants, and the entry and exit of plants, for aggregate trade and welfare.

The rest of the paper is organized as follows. Section 2 presents data for the aggregate and plant-level facts motivating the paper. Section 3 presents the model, section 4 contains the quantitative analysis, and Section 5 concludes.

2 Data

This section presents two sets of facts from the data that motivate the paper. First, trade flows at the aggregate level respond slowly to changes in relative prices across countries. Second, plant-level data show substantial heterogeneity in the use of imported inputs, and provide evidence on the importance of reallocation across importing and nonimporting plants in contributing to aggregate trade growth.

2.1 Aggregate Facts

Researchers estimating Armington elasticities – the elasticity of substitution between imported and domestic goods – rely on either business cycle fluctuations, or on single trade liberalization events, to generate variation in the price of imports relative to domestic goods. As Ruhl (2008) discusses, the estimates from cyclical fluctuations in prices imply small elasticities, mostly in the range of 1-3, while estimates from the growth in trade several years following trade liberalizations imply large elasticities, generally above 6. This difference in the short-run and long-run Armington elasticities implies that the response in trade flows to price changes takes time to develop.

[4]Kasahara (2004), using Chilean plant data, finds that a large change in the ratio of imports relative to domestic inputs within a plant is associated with a large concurrent investment in physical capital, interpreted as the adoption of a new technology.

This subsection establishes the magnitudes of the short-run and long-run aggregate Armington elasticities for Chile. First, I estimate a short-run elasticity following empirical studies such as Reinert and Roland-Holst (1992). I use annual data on trade and relative prices of imports to estimate the following equation by OLS:[5]

$$\log\left(\frac{M_t}{D_t}\right) = -\hat{\sigma}\log(p_t) + b \tag{1}$$

Here, M_t is imports, D_t is purchases of domestically produced goods, and p_t is the price of imports relative to domestic goods.The estimate of $\hat{\sigma}$ is the short-run Armington elasticity. An alternative estimate of the short-run elasticity is the ratio of volatilities of the left hand side of (1) divided by the right hand side,

$$\hat{\sigma} = \frac{\text{std}\left(\log\left(M_t/D_t\right)\right)}{\text{std}\left(\log\left(p_t\right)\right)} \tag{2}$$

Table 2 contains estimates of $\hat{\sigma}$ using both these methods.[6] The elasticity from the regression coefficient is about 2.9, while the ratio of volatilities gives an elasticity of about 3.6. These estimates are in the range commonly reported with high frequency data.

To estimate the long-run Armington elasticity, and to show that gradual growth in trade is important for explaning a high long-run elasticity, I turn to data on Chile's trade liberalization. Starting in 1974, Chile undertook a large, unilateral reduction in import tariffs. Figure 1 depicts the average tariff rate in manufacturing for 1973-2010 as well as the manufacturing import ratio, defined as the ratio of imports to purchases of domestic manufactured goods.[7] The figure shows that the large growth in imports was delayed relative to the large reduction in tariffs in the 70s. Figure 2 shows a time-varying Armington elasticity, calculated as the

[5]This equation is derived from the decision problem of a consumer with CES preferences over aggregate imports and domestic goods. Maximizing utility

$$U(M_t, D_t) = (\varpi D_t^{(\sigma-1)/\sigma} + (1-\varpi)M_t^{(\sigma-1)/\sigma})^{\sigma/(\sigma-1)}$$

subject to the budget constraint $D_t + p_t M_t \leq E$ for any expenditure E, gives (1) as the first order condition for the optimal M_t/D_t ratio, with the constant b depending on ϖ.

[6]The data are manufacturing imports, manufacturing exports, and manufacturing GDP, and wholesale prices for imported goods and for domestically produced goods, for the period 1962-2011. D_t is manufacturing GDP minus manufacturing exports. p_t is the ratio of the import wholesale price index to the domestic wholesale price index. Although the focus of the model in this paper is intermediate inputs, the aggregate data in this section are total manufacturing trade, because of data availability.

Trade and GDP data are from the World Bank's World Development Indicators, and the price indices are from the Chilean Central Bank's *Indicadores Económicos y Sociales de Chile: 1960 - 2000*, available at bcentral.cl/publicaciones/estadisticas/informacion-integrada/iei03.htm

[7]Trade and GDP data are as above. Chilean tariffs are simple average tariffs for all manufactured goods, from Ffrench-Davis and Saez (1995), Table 3 for 1973-1992, and from the World Bank's *World Development Indicators* for 1992-2010.

negative of the log change in the import ratio for any given year relative to 1973, divided by the log change in the average tariff, relative to 1973. This figure shows that the elasticity grows with the time since the liberalization, and that longer-horizon changes are larger than the short-run elasticities of $1-3$ estimated from the fluctuations in annual data. For example, the elasticity calculated from data in the mid 90s to the 2000s relative to 1973 is around $5-6$.

2.2 Plant-level Facts

This section describes data spanning 1979-1996 from Chile's annual industrial survey (*Encuesta Nacional Industrial Anual*) from the *Instituto Nacional de Estadistica* (*INE*). The data includes all manufacturing plants with at least 10 employees.[8] Each plant reports its total intermediate input purchases and the portion of its inputs that are "direct imports". If imports are positive, I consider the plant an importer.[9]

2.2.1 Cross-section

Few manufacturing plants in Chile use imported intermediate inputs, and they tend to be much larger than plants that do not use any imported inputs. Table 3 shows that only about 24 percent of plants, on average, use a positive amount of imported intermediate inputs. These plants employ about three times as many workers as plants that do not use imported inputs. Averaging over 1986-1996, during which there was a relatively more stable macroeconomic environment in Chile, gives essentially the same figures.

For comparison, Kurz (2006) reports that in 1992, about one quarter of US manufacturing plants used imported inputs, and they were on average about twice the size of the plants that did not. Using Indonesian firm-level data, Amiti and Konings (2007) report that about 20 percent of firms use imported inputs, and Halpern, Koren, and Szeidl (2009), show that about half of Hungarian firms import, and they are on average about five times larger than nonimporting plants.

Importing plants could be larger than nonimporters either because there are productivity/profitability gains to importing or because of selection. Empirical evidence suggests both factors are important. Kasahara and Rodrigue (2008), using the same Chilean plant-level data as in this paper, find that plants benefit from importing in terms of higher productivity after controlling for selection and other plant characteristics. Amiti and Konings (2007),

[8] The data are described in detail in Liu (1993).

[9] Under this classification, it is possible that some plants use imported inputs that come through wholesalers or retailers, and are not counted as importing plants in the data. In the calibration section, I discuss how this issue might affect the interpretation of the quantitative exercise.

Halpern, Koren, and Szeidl (2009) and Goldberg, Khandelwal, Pavcnik, and Topalova (2010) find similar results among Indonesian, Hungarian and Indian firms, respectively. But if there is a productivity gain from importing, the fact that most plants do not import suggests that importing is costly, so only more inherently profitable firms find it worthwhile to pay the costs of importing to exploit the productivity gains.

2.2.2 Panel

Since some plants import and some do not, changes in aggregate trade flows can be attributed to several different margins. Aggregate imports relative to total intermediate inputs can grow over a period of time because: (i) importing plants import relatively more of their inputs; (ii) importing plants grow relative to non-importing plants; (iii) non-importing plants start importing; or (iv) importing plants are more prevalent among new entrants than among exiting plants. I use the panel structure of the data to quantify the contribution of these margins to aggregate import growth in Chile over 1979-1996, using the following decomposition. Let M_t be the aggregate quantity, in year t, of imported inputs used at importing plants, and m_t^i denote imported inputs used by plant i in year t. Similarly, let A_t and a_t^i be quantities of total intermediate inputs (imported plus domestic).[10] Then, the change in aggregate imports relative to total intermediate goods between periods t and $t+1$ can be decomposed as follows:[11]

$$\begin{aligned}\frac{M_{t+1}}{A_{t+1}} - \frac{M_t}{A_t} \quad = \quad & \sum_{i \text{ imports in } t \text{ and } t+1} \left(\frac{m_{t+1}^i}{a_{t+1}^i} - \frac{m_t^i}{a_t^i} \right) \frac{x_{t+1}^i}{A_{t+1}} \\ & + \sum_{i \text{ imports in } t \text{ and } t+1} \left(\frac{a_{t+1}^i}{A_{t+1}} - \frac{a_t^i}{A_t} \right) \frac{m_t^i}{a_t^i} \\ & + \sum_{i \text{ imports in } t+1 \text{ but not } t} \frac{a_{t+1}^i}{A_{t+1}} \frac{m_{t+1}^i}{a_{t+1}^i} - \sum_{i \text{ imports in } t \text{ but not } t+1} \frac{a_t^i}{A_t} \frac{m_t^i}{a_t^i} \\ & + \sum_{i \text{ enters in } t+1} \frac{a_{t+1}^i}{A_{t+1}} \frac{m_{t+1}^i}{a_{t+1}^i} - \sum_{i \text{ exits in } t+1} \frac{a_t^i}{A_t} \frac{m_t^i}{a_t^i}\end{aligned} \tag{3}$$

The first line in the sum gives the total effect of each plant that imports in both years t and $t+1$ adjusting its ratio of imported to domestic inputs (m/a), weighted by its total share in the aggregate economy (a/A). This is adjustment within the plant. The second line

[10]Domestic and imported intermediate inputs are deflated with wholesale domestic and imported price indices, from the Chilean Central Bank's *Indicadores Económicos y Sociales de Chile: 1960 - 2000*, available at bcentral.cl/publicaciones/estadisticas/informacion-integrada/iei03.htm

[11]This is similar to the methodologies used by many authors to decompose aggregate productivity growth into its plant-level components. See, for example, Baily, Hulten, and Campbell (1992).

is the sum of changes in these continuously importing plants' share of the economy, holding fixed the intensity with which each plant uses imports. This is adjustment by reallocating inputs between plants. The third line is the contribution of continuing plants that start to import in year $t+1$, net of the loss due to continuing plants that no longer import in year $t+1$. Finally, the fourth line is the contribution of new entrants that import minus the loss due to importing plants that exit the economy. Table 4 gives the contributions of each of these four components, labeled "within", "between", "switch" and "net entry", respectively, as a percentage of the aggregate change $M_{t+1}/A_{t+1} - M_t/A_t$ (so that the components sum to one hundred). Two sets of figures are reported: the average across one-year changes, and the average of 5-year changes, where each term is weighted by the absolute value of that period's aggregate growth in M/A.

The figures in the first row of Table 4 show that, on average, each year, about 74 percent of the change in imports at the aggregate level is accounted for by each importing plant adjusting the ratio of imports relative to total intermediate inputs it uses. About 17 percent is accounted for by importing plants shrinking or growing in scale relative to non-importing plants. Only 2 percent of the aggregate change is accounted for by net entry, and about 6 percent is attributed to switching. The fact that the "between" component is substantial suggests that there is some irreversibility in the nature of the decision to import: not all the adjustment at the aggregate level comes from each plant changing the composition of goods it uses or from plants switching into or out of importing. In addition, the year-to-year net effects of entry and exit and of plants switching importing status are very small. In contrast, over the longer 5-year periods, the effects of switching and net entry accumulate, and contribute significantly more (14 percent for switching, 8 percent for net entry) to the aggregate change in imports than they do on average each year.

In the model presented in the next section, plants face a costly, irreversible decision to use imported intermediate inputs. This decision is partly irreversible, in that only a fraction of plants can switch between importing and not. The model generates both the cross-sectional properties of plant heterogeneity discussed in the previous subsection, and generates trade growth at the aggregate level through the within, between, and net entry margins discussed here. When calibrated to match the cross-sectional properties of the plant data, the model's time series behavior is consistent with the aggregate facts on the gradual growth in trade flows.

3 Model

The model consists of a small open economy in which production takes place in plants. Plants produce a homogeneous final good using labor and a continuum of intermediate goods as inputs, and receive idiosyncratic productivity shocks . They choose each period whether to use imported intermediate inputs or only domestically produced ones. Importing requires paying a fixed cost that depends on the plant's previous import status. Importing inputs provides two benefits: first, a wider variety of imperfectly substitutable goods, which raises output and measured TFP for a given level of a plant's productivity; second, importing raises the average productivity a plant faces. The idiosyncratic shocks to as well as aggregate shocks to the exogenous price of imports change the value of importing relative to not importing, and induce some plants to switch into and out of importing. Each period, some plants exogenously die, and new plants enter. A continuum of mass one of identical consumers own the plants, consume the final good they produce, and inelastically supply labor used in production.

3.1 Consumers

The preferences of a representative consumer are represented by the expected discounted present value of utility from consumption,

$$E_0 \sum_{t=0} \beta^t \frac{C_t^{1-\nu}}{1-\nu} \ ,$$

where $\beta \in (0,1)$ and $\nu > 0$, and C_t denotes consumption in period t. The consumer is endowed with one unit of time each period, and ownership of all plants in the economy. The consumer's budget constraint in period t is

$$C_t \leq w_t + \Pi_t \ ,$$

where w_t is the wage rate in units of domestic output in period t and Π_t is the aggregate profits of all plants operating in period t. There is no trade in financial markets.

3.2 Plants

Plants produce a homogenous final good using labor and a continuum of intermediate goods. Plants may choose to import some of their intermediate goods, but importing requires payment of a fixed cost. Plants receive idiosyncratic shocks to technological efficiency that change the relative profitability of importing, causing plants to start and stop importing over time. A plant's efficiency consists of a persistent component and a temporary component,

$$a_t = z_t + u_t \ ,$$

where u_t is drawn i.i.d. across plants and over time from a distribution with density $f_u(u)$, and z_t is drawn i.i.d. across plants from a Markov process with conditional density $f_z(z_{t+1}|z_t)$. There is also aggregate uncertainty over the price of imports relative to domestic goods, p_t, which follows a Markov process with conditional density $f_p(p_{t+1}|p_t)$. This section first lays out the plant's static decisions each period, then formulates plants' dynamic decision as a recursive problem.

3.2.1 Static profit maximization

A plant with efficiency a that uses N intermediate inputs in period t can produce output y of the homogeneous final good using labor and a continuum of intermediate inputs, labelled by ω, according to:

$$y_t = (e^a)^{1-\alpha-\theta} \ell_t^\alpha \left(\int_0^N x_t(\omega)^{\frac{\sigma-1}{\sigma}} d\omega \right)^{\theta \frac{\sigma}{\sigma-1}} , \tag{4}$$

where ℓ_t denotes labor input and $x_t(\omega)$ denotes units of intermediate input ω. Intermediates are combined with the constant elasticity of substitution $\sigma > 1$, and $\alpha + \theta < 1$. Final good plants all produce the same good, but since there are decreasing returns to scale in production, the economy has a nondegenerate distribution of plants, as in Lucas (1978).

This production technology is similar to that considered in Kasahara and Lapham (2007), and is related to the technologies featuring gains from variety in Ethier (1982) and Romer (1990). Importing and nonimporting plants differ in the range of intermediate inputs they use. Specifically, if a plant is not using imported inputs, then $N = n$, and is a plant uses imported inputs, then $N = n + n^*$. Here, n denotes the mass of domestically produced inputs, and n^* is the mass of foreign-produced inputs.

Domestic intermediate inputs are produced using inputs of the final good. One unit of the final good can be used to produce one unit of any of the n domestic intermediate inputs, so that all these inputs have a price of 1 in units of the final good. Imported inputs of all n^* varieties have price p_t.

Plants are perfectly competitive, and maximize profits by choosing labor and intermediate inputs subject to the technology (4), taking as given the price p_t and the wage rate w_t. Since all domestic inputs have the same price and all imported inputs have the same price, and they enter the production function symmetrically, a final good plant will choose to use equal quantities of all domestic inputs and, if it imports, equal quantities of all imported inputs.[12] Therefore, it is convenient to restrict attention in the plants' problems to choices of the form:

$$x_t(\omega) = \begin{cases} d_t \text{ if } \omega \in [0, n] \\ m_t \text{ if } \omega \in (n, n+n^*] \end{cases}$$

so that the per-period profit for a nonimporting plant with efficiency a can be written:

$$\pi_{dt}(a) = \max_{\ell,d} (e^a)^{1-\alpha-\theta} \ell^\alpha n^{\frac{\theta\sigma}{\sigma-1}} d^\theta - w_t \ell - nd$$

while for an importing plant:

$$\pi_{mt}(a) = \max_{\ell,d,m} (e^a)^{1-\alpha-\theta} \ell^\alpha \left(nd^{\frac{\sigma-1}{\sigma}} + n^* m^{\frac{\sigma-1}{\sigma}}\right)^{\theta\frac{\sigma}{\sigma-1}} - w_t \ell - nd - p_t n^* m$$

where the subscripts d and m refer to nonimporting and importing plants, respectively.

Let $\ell_{dt}(a), d_{dt}(a)$ and $\ell_{mt}(a), d_{mt}(a), m_t(a)$ denote the optimal input choices for nonimporting and importing plants, respectively in period t. For nonimporting plants, these are given by:

$$\begin{aligned} \ell_{dt}(a) &= e^a \frac{\alpha}{w_t} h_{dt}^{1/(\alpha+\theta-1)} \\ d_{dt}(a) &= e^a \frac{\theta}{n} h_{dt}^{1/(\alpha+\theta-1)} \\ y_{dt}(a) &= e^a h_{dt}^{1/(\alpha+\theta-1)} \end{aligned} \tag{5}$$

where

$$h_{dt} = \left(n^{1/(1-\sigma)}/\theta\right)^\theta (w_t/\alpha)^\alpha \tag{6}$$

is the price index of the composite input bundle common to all nonimporting plants. Profits of a nonimporting plant are given by $\pi_{dt}(a) = (1-\alpha-\theta) y_{dt}(a)$.

[12] To keep the dynamic model tractable, I abstract from differences in import intensity across importing plants. Halpern, Koren, and Szeidl (2009), Gopinath and Neiman (2011) and Ramanarayanan (2012) develop models that capture these differences.

For importing plants, the optimal input and output decisions are:

$$\begin{aligned}
\ell_{mt}(a) &= e^a \frac{\alpha}{w_t} h_{mt}^{1/(\alpha+\theta-1)} \\
d_{mt}(a) &= e^a \frac{\theta}{n + n^* p_t^{1-\sigma}} h_{mt}^{1/(\alpha+\theta-1)} \\
m_t(a) &= d_{mt}(a)\, p_t^{-\sigma} \\
y_{mt}(a) &= e^a h_{mt}^{1/(\alpha+\theta-1)}
\end{aligned} \tag{7}$$

where the analogous input cost for importing plants is:

$$h_{mt} = \left((n + n^* p_t^{1-\sigma})^{\frac{1}{1-\sigma}} / \theta \right)^{\theta} (w_t/\alpha)^{\alpha} \tag{8}$$

and importing plants' profits are given by $\pi_{mt}(a) = (1 - \alpha - \theta)\, y_{mt}(a)$.

Plant sizes (measured by outputs or inputs) are proportional to e^a. In addition, importing plants are bigger than nonimporting plants for a given a according to any of these measures, because $h_{mt} < h_{dt}$ and $\alpha + \theta < 1$.

Plant-level gain from importing Importing plants have a cost advantage in production because the intermediate input bundle is cheaper for an importing plant than for a nonimporting plant. The price index for a nonimporting plant to form one unit of the composite intermediate input it uses in production, $\left(nd^{(\sigma-1)/\sigma}\right)^{\sigma/(\sigma-1)}$, is equal to:

$$q_{dt} = n^{1/(1-\sigma)}$$

while for an importing plant to produce one unit of the composite $\left(nd^{(\sigma-1)/\sigma} + n^* m^{(\sigma-1)/\sigma}\right)^{\sigma/(\sigma-1)}$, the price index is:

$$q_{mt} = (n + n^* p_t^{1-\sigma})^{1/(1-\sigma)}$$

For any finite p, $q_m < q_d$, because $\sigma > 1$. This gain from a higher variety of intermediate inputs is the same as the increasing return to variety considered in Ethier (1982) and Romer (1990), and shows up as higher productivity in terms of total expenditures on intermediate inputs. For a nonimporting plant, expenditures are:

$$x_{dt}(a) = n d_{dt}(a)$$

For a nonimporting plant, the cost-minimizing way to spend $x_{mt}(a)$ on the composite input $\left(nd^{(\sigma-1)/\sigma}+n^{*}m^{(\sigma-1)/\sigma}\right)^{\sigma/(\sigma-1)}$ is:

$$\begin{aligned} d_{mt}(a) &= q_{mt}^{\sigma-1}x_{mt}(a) \\ m_{t}(a) &= \left(q_{mt}/p_{t}\right)^{\sigma-1}x_{mt}(a) \end{aligned}$$

Therefore, output of nonimporting and importing plants can be written:

$$\begin{aligned} y_{dt}(a) &= \left(e^{a}\right)^{1-\alpha-\theta}\ell_{dt}(a)^{\alpha}\,n^{\frac{\theta}{\sigma-1}}x_{dt}(a)^{\theta} \\ y_{mt}(a) &= \left(e^{a}\right)^{1-\alpha-\theta}\ell_{mt}(a)^{\alpha}\left(n+n^{*}p_{t}^{1-\sigma}\right)^{\frac{\theta}{\sigma-1}}x_{mt}(a)^{\theta} \end{aligned}$$

An importing plant can produce $\left(1+\frac{n^{*}}{n}p_{t}^{1-\sigma}\right)^{\theta/(\sigma-1)}$ more units of output than a nonimporting plant with the same expenditures on labor and intermediate inputs. The magnitude of this productivity advantage depends on the share of intermediates in production, θ, and the elasticity of substitution σ. It also depends on the price p_t and the measures of goods n and n^*, but for a given ratio of expenditure on imports relative to domestic goods, $\psi_t \equiv \frac{p_t n^* m_t(a)}{n d_{mt}(a)} = \frac{n^*}{n}p_t^{1-\sigma}$, the productivity of an importing plant relative to a nonimporting plant with the same efficiency a can be written:

$$\frac{y_{mt}(a)/[\ell_{mt}(a)^{\alpha}x_{mt}(a)^{\theta}]}{y_{dt}(a)/[\ell_{dt}(a)^{\alpha}x_{dt}(a)^{\theta}]} = \left(1+\psi_t\right)^{\frac{\theta}{\sigma-1}}$$

which is increasing in the importance of intermediate inputs in production, θ, and the ratio ψ of imports to domestic expenditures, and decreasing in the elasticity of substitution, σ. If $\sigma > 1$, the additional varieties of intermediate inputs gained from importing raise productivity, but as σ increases, input varieties become more substitutable and the productivity gain of importing falls.

3.2.2 Plants' dynamic problem

The timing of a plant's decisions are as follows. At the beginning of period t, a plant has decided to either import or not. The plant observes the realizations of the idiosyncratic shocks z_t and u_t, and the aggregate shock p_t, then makes input and output decisions according to the within-period problems described in the previous subsection. Profits in period t are $\pi_{dt}(z_t+u_t)$ if the plant is not importing or $\pi_{mt}(z_t+u_t)$ if the plant is importing. With probability δ, the plant exogenously exits at the end of period t. An importing plant that survives decides whether to continue importing in $t+1$, which requires paying a fixed cost ϕ_1 in units of period t output. A nonimporting plant that survives faces a friction in deciding whether to switch to importing: with probability η, a nonimporting plant decides whether to switch to importing by paying a fixed cost ϕ_0 in period t, and with probability $1-\eta$, the plant automatically continues not importing.

Plants' importing decisions only depend on their forecasts of the persistent part of productivity, z, so it is convenient to write the expected discounted value of profits from period t on averaged across realizations of u, e.g. $\tilde{\pi}_{dt}(z) = \int \pi_{dt}(z+u) f_u(u)\, du$. Formulated recursively, the state variable for a plant's decision problem is (z, p, μ_d, μ_m) where p is the current price of imports, and $\mu_d(z), \mu_m(z)$ are the current distributions of nonimporting and importing plants, respectively, across values of z. Call $\mu = (\mu_d, \mu_m)$ the aggregate endogenous state variable and let $V_d(z, p, \mu)$ and $V_m(z, p, \mu)$ be the expected present discounted value of profits for a nonimporting and an importing plant, respectively, with persistent productivity level z. These are given by:

$$
\begin{aligned}
V_d(z,p,\mu) \;=\; & \lambda(p,\mu)\,\tilde{\pi}_d(z,p,\mu) + (1-\eta)\,\beta\,(1-\delta)\int\!\!\int V_d(z',p',\mu')\, f_z(z'|z)\, f_p(p'|p)\, dz'dp' \\
& + \eta \max\Big\{ -\lambda(p,\mu)\,\phi_0 + \beta\,(1-\delta)\int\!\!\int V_m(z',p',\mu')\, f_z(z'|z)\, f_p(p'|p)\, dz'dp', \\
& \beta\,(1-\delta)\int\!\!\int V_d(z',p',\mu')\, f_z(z'|z)\, f_p(p'|p)\, dz'dp' \Big\}
\end{aligned}
$$

$$
\begin{aligned}
V_m(z,p,\mu) \;=\; & \lambda(p,\mu)\,\tilde{\pi}_m(z,p,\mu) \\
& + \max\Big\{ -\lambda(p,\mu)\,\phi_1 + \beta\,(1-\delta)\int\!\!\int V_m(z',p',\mu')\, f_z(z'|z)\, f_p(p'|p)\, dz'dp', \\
& \beta\,(1-\delta)\int\!\!\int V_d(z',p',\mu')\, f_z(z'|z)\, f_p(p'|p)\, dz'dp' \Big\}
\end{aligned}
$$

where, in each equation, plants take as given the law of motion for the endogenous aggregate state variable, $\mu' = H(p,\mu)$, and the function $\lambda(p,\mu) = C(p,\mu)^{-\nu}$. Plants value profits each period in units of the household's marginal utility to reflect the household's ownership. Finally, new plants decide whether to enter and whether to import in their first period. A new entrant pays a sunk cost to draw an initial signal $z \sim g(z)$, and then decides whether to import or only use domestic inputs starting in the next period. The cost of importing for an entrant is κ_m. Expected discounted profit for an entering plant with signal z is

$$
V_e(z,p,\mu) = \max\Big\{ \beta\int\!\!\int V_d(z',p',\mu')\, f_z(z'|z)\, f_p(p'|p)\, dz'dp', -\lambda(p,\mu)\,\kappa_m + \beta\int\!\!\int V_m(z',p',\mu')\, dz'dp' \Big\}
$$

Plant's dynamic decisions take the form of cutoff rules, specified by three values, $\hat{z}_m(p,\mu)$

(for new entrants), $\hat{z}_0(p,\mu)$ (for continuing plants that were not importing), and $\hat{z}_1(p,\mu)$ (for continuing plants that were importing): if a plant's current z is above the cutoff, the plant chooses to import in the next period. These cutoffs satisfy:

$$\begin{aligned}
\lambda(p,\mu)\kappa_m &= \beta\int\int\left[V_m(z',p',\mu')-V_d(z',p',\mu')\right]f_z(z'|\hat{z}_m(p,\mu))f_p(p'|p)\,dz'dp' \\
\lambda(p,\mu)\phi_0 &= \beta(1-\delta)\int\int\left[V_m(z',p',\mu')-V_d(z',p',\mu')\right]f_z(z'|\hat{z}_0(p,\mu))f_p(p'|p)\,dz'dp' \\
\lambda(p,\mu)\phi_1 &= \beta(1-\delta)\int\int\left[V_m(z',p',\mu')-V_d(z',p',\mu')\right]f_z(z'|\hat{z}_1(p,\mu))f_p(p'|p)\,dz'dp'
\end{aligned}$$

3.3 Equilibrium

The evolution of the distributions μ_d and μ_m determine the aggregate law of motion $\mu' = H(p,\mu)$ which plants use to forecast future profits. The mass of plants that enter when the aggregate state is (p,μ) is $X(p,\mu)$. The laws of motion for the distributions are:

$$\begin{aligned}
\mu'_d(z') &= (1-\delta)\left[\int_{-\infty}^{\hat{z}_0(p,\mu)}\mu_d(z)f(z'|z)\,dz+(1-\eta)\int_{\hat{z}_0(p,\mu)}^{\infty}\mu_d(z)f(z'|z)\,dz+\int_{-\infty}^{\hat{z}_1(p,\mu)}\mu_m(z)f(z'|z)\,dz\right] \\
&\quad +X(p,\mu)\int_{-\infty}^{\hat{z}_m(p,\mu)}g(z)f(z'|z)\,dz
\end{aligned}$$

$$\mu'_m(z') = (1-\delta)\left[\eta\int_{\hat{z}_0(p,\mu)}^{\infty}\mu_d(z)f(z'|z)\,dz+\int_{\hat{z}_1(p,\mu)}^{\infty}\mu_m(z)f(z'|z)\,dz\right]+X(p,\mu)\int_{\hat{z}_m(p,\mu)}^{\infty}g(z)f(z'|z)\,dz$$

The value of entry satisfies:

$$\int V_e(z,p,\mu)g(z)\,dz - C(p,\mu)^{-\nu}\kappa_e \leq 0$$

with equality if $X(p,\mu)>0$.

Let $L_d(p,\mu)$ denote the total labor used by nonimporting plants in period t,

$$L_d(p,\mu)=\int\int \ell_d(z+u,p,\mu)h(u)\mu_d(z)\,dudz$$

with $\ell_d(a,p,\mu)$ given by (5) evaluated at $p_t=p$ and $w_t=w(p,\mu)$. Define L_m and intermediate inputs and gross outputs D_d, D_m, M, Y_d, Y_m analogously. The labor market clearing condition is

$$L_d(p,\mu)+L_m(p,\mu)=1$$

and the goods market clearing condition is:

$$Y_d(p,\mu) + Y_m(p,\mu) = C(p,\mu) + D_d(p,\mu) + D_m(p,\mu) + pM(p,\mu)$$
$$+\phi_0\eta\int_{\hat{z}_0(p,\mu)}^{\infty}\mu_d(z)\,dz + \phi_1\int_{\hat{z}_0(p,\mu)}^{\infty}\mu_m(z)\,dz + X(p,\mu)\left[\kappa_e + \left(1 - G\left(\hat{z}_m(p,\mu)\right)\right)\phi_0\right]$$

4 Quantitative Analysis

In this section, I calibrate the model to several features of the Chilean plant level and macroeconomic data, and simulate it in response to both transitory and permanent changes in the relative price of imports. I decompose the margins of trade growth in a simulated time series and compare the contributions of these margins to those in the data. Without frictions in switching to importing, the model generates an excessively large contribution of switching to import growth, and a short-run Armington elasticity that is above 4. Simulating the model with the switching friction lowers the contribution of switching to aggregate import growth by about half, and lowers the short-run elasticity by about one, bringing both these statistics closer in line with the data.

4.1 Calibration

I set some parameters to standard values in the international macro literature, and choose the remainder to match certain cross-sectional moments of the Chilean plant-level data. Table 5 summarizes the calibration. The model period is one year, and I set the discount factor $\beta = 0.96$, which implies a real interest rate of 4% per year. I set the parameter ν in the household's per-period utility function $C_t^{1-\nu}/(1-\nu)$ to $\nu = 2$, a standard value in international business cycle models (e.g. Backus, Kehoe, and Kydland (1994)).

The stochastic process for p_t is an AR(1) in logs,

$$\log p_{t+1} = \left(1-\rho_p\right)\log\bar{p} + \rho_p \log p_t + \varepsilon_{pt+1} \tag{9}$$

with $\varepsilon_{pt+1} \sim N\left(0, \eta_\varepsilon^2\right)$. I use data on Chilean import and domestic wholesale price indices from the IMF's *International Financial Statistics* to construct a series for the relative price of imports, and set ρ to the autocorrelation of the series over 1979-1996, and η_ε to the standard deviation of the residuals of (9). This procedure gives $\rho_p = 0.895$ for the autocorrelation of $\log p_t$ and $\eta_\varepsilon = 0.028$ for the standard deviation of the shocks. In my model, fluctuations in the relative price of imports p_t stand in for a variety of shocks such as unilateral changes in tariffs, real exchange rate movements, and commodity price fluctuations. While these different shocks would be expected to vary in their persistence and volatility, I use one aggregate shock for ease of illustration. In addition, the period 1979-1996 was after the end of a long series of changes in trade policy in Chile, and aside from a temporary increase in tariffs in 1983-84 (which shows up in the relative import price data used), there were no major permanent changes in trade policy over this period (de la Cuadra and Hachette (1991)).

The remaining parameters are either calculated directly or calibrated to match moments from the Chilean plant-level data, over the period 1979-1996. The parameters of the plant production functions that are common between non-importing plants and importing plants are α, the share of output spent on labor compensation, and θ, the share of output spent on intermediate inputs. I calculate labor compensation and intermediate expenditures as fractions of gross output. Since I exclude other factors of production, I scale up these expenditure shares so that the overall share of profits in output is $1-\alpha-\theta=0.15$, a value Atkeson and Kehoe.

The parameter σ is the elasticity substitution between different inputs at the plant level, and also the plant-level elasticity of substitution between imported and domestic inputs. In the model, as long as a plant continuously imports across periods, they substitute between imports and domestic goods with elasticity σ. Therefore, I use the aggregate of imports and domestic inputs across all plants in the data that continuously import over the sample period, $\{M_t^c, D_t^c\}_{t=1979.....1996}$, and compute σ as the ratio of the volatility of this aggregate import ratio:

$$\sigma = \frac{\text{std}\left(\log M_t^c / D_t^c\right)}{\text{std}\left(\log p_t\right)} \ . \tag{10}$$

This yields a value of σ of 2.4. The share of expenditures on imports at importing plants in the model, $\frac{\bar{\psi}}{1+\bar{\psi}}$, pins down the factor $\frac{n^*}{n}\bar{p}^{1-\sigma}$. Given a value for σ, this does not identify n^*, n, and $\bar{p}$ separately, so I set $n=n^*=1$ and choose $\bar{p}$, the average relative import price, to match the average plant-level import share of 31 percent. Given an average import share, the parameter σ also determines the productivity advantage of importing plants relative to nonimporting ones, which is equal to $\left(1+\bar{\psi}\right)^{\frac{\theta}{\sigma-1}}$ in a steady state, where $\bar{\psi}$ is the ratio of expenditures on imports to domestic inputs at importing plants. At an import share of 31 percent, the values for θ and σ imply an average productivity gain from importing of 18.5 percent. This value lies in the range of estimates in Kasahara and Rodrigue (2008), who directly estimate the productivity advantage of importing plants in Chilean plant-level data. Several other papers, such as Halpern, Koren, and Szeidl (2009) and Muendler (2004), estimate a similar statistic in other plant- and firm-level data sets, and find a smaller advantage of importing. In addition, as mentioned in Section 2, the plant-level data do not report the likely nonzero amount of imported inputs at smaller plants that are purchased through wholesalers or retailers. Ignoring these other plants' imports likely overstates the productivity advantage of importing. For these reasons, I also consider how different values change the choice of σ and the quantitative results in the sensitivity analysis below.

I set $\delta = .036$, which is the average exit rate of plants. I normalize the cost of entry $\kappa_e = 0.1$; changing this parameter has no effect on any of the statistics I examine, since the remaining calibated fixed cost parameters are scaled proportionally to match the remaining moments.

The persistent part of plant-level efficiency, z_t, follows an AR(1) process with mean zero,

$$z_{t+1} = \rho_z z_t + \varepsilon_{zt+1}$$

where $\varepsilon_{zt+1} \sim N(0, \sigma_z^2)$, and the transitory part $u_t \sim N(0, \sigma_u^2)$. I estimate ρ_z from the persistence of plant-level input decisions, as follows. Total input expenditures at a nonimporting plant in the model are:

$$x_t = e^{z_t + u_t} \frac{\theta}{n} h_{dt}^{1/(\alpha+\theta-1)}$$

so that

$$\begin{aligned} \log x_{t+1} &= \rho_z z_t + \varepsilon_{zt+1} + u_{t+1} + \log\left(\frac{\theta}{n} h_{dt+1}^{1/(\alpha+\theta-1)}\right) \\ &= \rho_z \left(\log x_t - \log\left(\frac{\theta}{n} h_{dt}^{1/(\alpha+\theta-1)}\right) - u_t\right) + \varepsilon_{zt+1} + u_{t+1} + \log\left(\frac{\theta}{n} h_{dt+1}^{1/(\alpha+\theta-1)}\right) \\ &= \rho_z \log x_t - \rho_z \left(\log\left(\frac{\theta}{n} h_{dt}^{1/(\alpha+\theta-1)}\right) + u_t\right) + \varepsilon_{zt+1} + u_{t+1} + \log\left(\frac{\theta}{n} h_{dt+1}^{1/(\alpha+\theta-1)}\right) \\ &= \rho_z \log x_t + v_{t+1} - \rho_z v_t + \xi_{t+1} \end{aligned} \tag{11}$$

where v_{t+1}, v_t are common to all plants, and $\xi_{t+1} = \varepsilon_{zt+1} + u_{t+1} - \rho_z u_t$ has variance $\sigma_x^2 = \sigma_z^2 + (1 + \rho_z^2)\sigma_u^2$. I estimate ρ_z from (11) using OLS using the set of plants who never use imported inputs, proxying for the $v_{t+1} - \rho_z v_t$ term with year dummies. This gives a coefficient of $\rho_z = 0.926$ (with standard error .0027). I then choose the variance σ_z^2, the fixed costs κ_m, ϕ_0, ϕ_1, to jointly match four cross-sectional moments in the plant-level data: the fraction of plants importing; the average size of importing plants relative to nonimporting plants, as measured by intermediate inputs; and the two annual switching rates of nonimporting plants starting to import and importing plants stopping. Although these four parameters jointly determine the values of these four statistics in the model, intuitively, κ_m pins down the overall fraction of plants importing, while ϕ_0 and ϕ_1 largely determine the switching rates, and σ_z^2 affects the size ratio. A higher σ_z^2 means shocks to persistent efficiency are larger, so the average size of importing plants relative to nonimporting plants is higher. Given a value for σ_z^2 and an estimate of the residual variance σ_x^2 from the regression (11), which is $(0.54)^2$, I calculate $\sigma_u^2 = \frac{\sigma_x^2 - \sigma_z^2}{1+\rho_z^2}$.

In the model with a switching friction, I choose η to match the average size of plants that start importing relative to the average size of importing plants, which is 0.64 in the data, keeping the other targets the same. Given a target for a switching rate, η controls the size of the selection effect due to the fixed cost of switching to importing. A lower η means a lower probability of being able to switch, so that among those who do receive the opportunity, the switching rate must be higher, so the cutoff $\hat{z}_0$ lower. Therefore, selection effect is weakened – and the average efficiency and size of switching plants declines – as η decreases.

4.2 Short-run fluctuations

I simulate the two models – with and without the switching friction – with shocks to p_t drawn from the stochastic process described in the previous subsection, to evaluate the model's predictions regarding short-run fluctuations in trade volumes. As in Ruhl (2008), I estimate the short-run Armington elasticity from model-generated time series of M_t, D_t, and the price p_t. The results are in Table 6.

The first two columns of Table 6 contain estimates of the short-run Armington elasticity in the models. The first number is the coefficient in the same regression as in the data, equation (1). The second coefficient is the ratio of standard deviations of the left hand and right hand sides of (1), since the equation implies

$$\hat{\sigma} = \frac{\text{std}\left(\log\left(M_t/D_t\right)\right)}{\text{std}\left(\log\left(p_t\right)\right)} \tag{12}$$

In the model with no switching friction, these elasticities are both above 4.5, which is over 50% larger than the short-run elasticity estimated from the aggregate Chilean data. In addition, Ruhl (2008) finds that a broad set of empirical estimates of this elasticity are in the range of about 0.2 to 3, so the elasticity implied by this model is well above the range of short-run elasticities estimated in literature. The last four columns of the table perform the same decomposition as in the data, to illustrate the plant-level movements behind this large elasticity. In the model with no switching friction, the contribution of switching is an order of magnitude larger than in the data, accounting for over half the year-to-year fluctuations in the aggregate import share.

By contrast, in the model with the switching friction, the short-run elasticity is smaller, at 3.65 (or 3.69 from the volatility ratio), although still larger than in the data. The plant-level decomposition shows that lowering η to the value calibrated in the data reduces the size of the switching contribution by more than half compared to the model with no friction, bringing it and the rest of the decomposition closer in line with the data. This reduction in the contribution of switching occurs because the calibrated value of η implies that most plants that get the chance to switch do pay the cost to switch. Therefore, fluctuations in the cutoff z_t^0 brought about by aggregate fluctuations in p_t have a relatively small impact on the fraction of plants above the cutoff, since it is already so large.

4.3 Dynamics of Trade Reform

I now consider the model's dynamic response to an unanticipated, permanent reduction of 10% in the relative price of imports, in the absence of any other shocks to p_t.[13]

Table 7 presents measures of the magnitude and speed of the growth in trade following trade reform. The first panel shows growth rates across steady states and growth rates one and ten years after the import price reduction, in the import ratio and the import share. In the model with no switching friction, both the ratio of imports to domestic goods and the share of imports in total inputs reach about 94 percent of their eventual growth within ten years. In the model with the switching friction, this number is a bit lower, at 88 percent.

Table 7 also shows the implied Armington elasticity at different time horizons following the drop in p_t. At each time $t = 1$, 10, and ∞, where ∞ denotes the new free-trade steady state, the elasticity is calculated as the percentage increase in the ratio M_t/D_t relative to the original steady state, divided by the change in the relative price, reflected in the tariff reduction. That is,

$$\sigma_t = \frac{\left(\frac{M_t/D_t}{\bar{M}/\bar{D}} - 1\right)}{\left(\frac{p_t}{\bar{p}} - 1\right)}$$

where $\bar{M}/\bar{D}$ is the original steady state ratio. Note that for this experiment, $p_1 = p_{10} = p_\infty = 0.90 \times \bar{p}$.

After one year, the growth in trade implies an elasticity of about 3.5, in both models, which is similar to that estimated in response to business cycle fluctuations. After 10 years, the measured elasticity is about 6.9 in the model with no friction, and about 5.9 in the model with the switching friction. Across steady states, the implied elasticities are about 7.4 and 6.6, respectively. Therefore, both models generate a long-run elasticity that is significantly higher than the short-run elasticity, but the switching friction is important in getting the short-run elasticity and the plant-level decomposition closer to the data.

[13] I compute the equilibrium path assuming that the model reaches its new steady state 100 years after the tariff reduction. This time horizon is long enough that increasing it does not significantly affect the results.

Finally, the adjustment in aggregate quantities following trade liberalization suggests that there could be significant consequences for the welfare gains from trade reform. In particular, there is an initial increase in the fraction of plants that import (from all groups: new entrants, previous nonimporters, and previous importers), that gradually subsides as real wages rise to offset the gains form importing. This means that welfare gains taking into account the transition are higher than comparing across steady states. To quantify this effect, I compare two measures of welfare gains. The first measure compares lifetime utility across steady states, by calculating the percentage increase in the original steady state's consumption needed to attain the level of lifetime utility at the new steady state. This is the factor λ_S that solves:

$$U(\lambda_S \bar{C}) = U(\tilde{C})$$

where $\bar{C}$ and $\bar{L}$ are consumption and labor supply in the original steady state, and $\tilde{C}$ and $\tilde{L}$ are for the new steady state. The second measure of welfare gains computes an analogous consumption-variation measure, comparing lifetime utility the initial steady state to utility over the entire transition to the new steady state. That is, the second measure is the factor λ_T that solves:

$$U(\lambda_T \bar{C}) = \sum_{t=0}^{\infty} \beta^t U(C_t)$$

where C_t and L_t are consumption and labor supply t periods following the trade reform.

The bottom panel of Table 4 shows the two measures λ_S and λ_T. In the model with no switching friction, welfare including the transition is about 47 percent larger than the steady state comparison. In the model with the switching friction, λ_T is still larger than λ_S, but by only half as much, about 23 percent. These results show that the welfare calculation based on a static model would underestimate the welfare gains, but the presence of the switching friction mitigates this difference.

5 Conclusion

This paper has constructed a model of international trade in intermediate inputs used by heterogeneous plants. The calibrated model generates a low degree of aggregate substitution between imports and domestic goods in the short-run, mostly due to adjustment within importing plants and reallocation between importing and nonimporting plants, in line with data. However, in response to a permanent trade liberalization, the set of plants in the economy gradually changes, and a higher proportion of new plants import intermediates.

The model provides a framework for analyzing the dynamic effects of trade policy through changes in producer-level importing decisions. With irreversibility in these decisions, changes in trade policy have both static and dynamic effects on the allocation of resources across plants that import and plants that do not. Since trade grows slowly, the welfare gain from trade liberalization is lower than in a model in which all the adjustment is immediate.

The model here has focused on the plant-level decision to import, motivated by recent empirical evidence of the importance of this decision. A large body of evidence exists as well for the importance of the plant-level exporting decision, and a useful extension would be a dynamic model that integrates the plant-level importing decisions introduced here with the exporting decisions analyzed in much of the recent trade literature.

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6 Appendix

6.1 Social planner's problem

Since there are no distortions, an equilibrium solves a planning problem of maximizing the consumer's utility subject to the feasibility constraints. The planning problem is

$$\max \sum_{t=0}^{\infty} \beta^t \frac{C_t^{1-\nu}}{1-\nu}$$

subject to:

$$C_t + D_{dt} + D_{mt} + p_t M_t + X_t \left(\kappa_e + \kappa_m \left[1 - G\left(\hat{z}_{mt}\right)\right]\right) + \phi_0 \eta \int_{\hat{z}_{0t}}^{\infty} \mu_{dt}\left(z\right) dz + \phi_1 \int_{\hat{z}_{1t}}^{\infty} \mu_{mt}\left(z\right) dz$$

$$= \left(Z_{dt}\right)^{1-\alpha-\theta} L_{dt}^{\alpha} n^{\frac{\theta}{\sigma-1}} D_{dt}^{\theta} + \left(Z_{mt}\right)^{1-\alpha-\theta} L_{mt}^{\alpha} \left(n^{1/\sigma} D_{mt}^{\frac{\sigma-1}{\sigma}} + \left(n^*\right)^{1/\sigma} M_t^{\frac{\sigma-1}{\sigma}}\right)^{\theta \frac{\sigma}{\sigma-1}}$$

$$L_{dt} + L_{mt} = 1$$

$$\mu_{dt+1}\left(z'\right) = \left(1-\delta\right)\left[\int_{-\infty}^{\hat{z}_{0t}} \mu_{dt}\left(z\right) f\left(z'|z\right) dz + \left(1-\eta\right) \int_{\hat{z}_{0t}}^{\infty} \mu_{dt}\left(z\right) f\left(z'|z\right) dz + \int_{-\infty}^{\hat{z}_{1t}} \mu_{mt}\left(z\right) f\left(z'|z\right) dz\right] + X_t \int_{-\infty}^{\hat{z}_{mt}} g\left(z\right) f\left(z'|z\right) dz$$

$$\mu_{mt+1}\left(z'\right) = \left(1-\delta\right)\left[\eta \int_{\hat{z}_{0t}}^{\infty} \mu_{dt}\left(z\right) f\left(z'|z\right) dz + \int_{\hat{z}_{1t}}^{\infty} \mu_{mt}\left(z\right) f\left(z'|z\right) dz\right] + X_t \int_{\hat{z}_{mt}}^{\infty} g\left(z\right) f\left(z'|z\right) dz$$

where

$$Z_{dt} = e^{\sigma_u^2} \int_{-\infty}^{\infty} e^z \mu_{dt}\left(z\right) dz$$

$$Z_{mt} = e^{\sigma_u^2} \int_{-\infty}^{\infty} e^z \mu_{mt}\left(z\right) dz$$

and letting λ_t denote the multiplier on aggregate the resource constraint; w_t the multiplier on the labor feasibility constraint; and $r_{dt}\left(z'\right), r_{mt}\left(z'\right)$ the multipliers on the laws of motion for μ_{dt} and μ_{mt}, the first order conditions of the planning problem lead to:

$$\lambda_t = u'\left(C_t\right)$$

$$L_{dt} = Z_{dt}\left(n^{\frac{\theta}{\sigma-1}} \theta^{\theta} \left(\frac{w_t}{\alpha \lambda_t}\right)^{\theta-1}\right)^{1/(1-\alpha-\theta)}$$

$$D_{dt} = \frac{w_t}{\lambda_t} \frac{\theta}{\alpha} L_{dt}$$

$$L_{mt} = Z_{mt}\left(\left(\frac{w_t}{\lambda_t \alpha}\right)^{\theta-1}\theta^\theta n^{\frac{\theta}{\sigma-1}}\left(1+\left(\frac{n^*}{n}\right)p_t^{1-\sigma}\right)^{\frac{\theta}{\sigma-1}}\right)^{1/(1-\alpha-\theta)}$$

$$M_t = p_t^{-\sigma}\frac{n^*}{n}D_{mt}$$

$$D_{mt} = \frac{w_t}{\lambda_t \alpha}\frac{\theta}{1+\frac{n^*}{n}p_t^{1-\sigma}}L_{mt}$$

$$\lambda_t\left(\kappa_e + \kappa_m\left[1-G\left(\hat{z}_{mt}\right)\right]\right) = \int_{-\infty}^{\infty} r_{dt}\left(z'\right)\left[\int_{-\infty}^{\hat{z}_{mt}} g(z) f\left(z'|z\right)dz\right]dz' + \int_{-\infty}^{\infty} r_{mt}\left(z'\right)\left[\int_{\hat{z}_{mt}}^{\infty} g(z) f\left(z'|z\right)dz\right]dz'$$

$$\lambda_t \kappa_m = \int_{-\infty}^{\infty}\left[r_{mt}\left(z'\right) - r_{dt}\left(z'\right)\right] f\left(z'|\hat{z}_{mt}\right)dz'$$

$$\lambda_t \phi_0 = (1-\delta)\int_{-\infty}^{\infty}\left[r_{mt}\left(z'\right) - r_{dt}\left(z'\right)\right] f\left(z'|\hat{z}_{0t}\right)dz'$$

$$\lambda_t \phi_1 = (1-\delta)\int_{-\infty}^{\infty}\left[r_{mt}\left(z'\right) - r_{dt}\left(z'\right)\right] f\left(z'|\hat{z}_{1t}\right)dz'$$

$$r_{dt}\left(z'\right) = \beta\lambda_{t+1}\left[(1-\alpha-\theta)Z_{dt+1}^{-\alpha-\theta}e^{\sigma_u^2}e^{z'}L_{dt+1}^{\alpha}n^{\frac{\theta}{\sigma-1}}D_{dt+1}^{\theta} - \phi_0\eta\mathbb{I}_{\{z'\geq\hat{z}_{0t+1}\}}\right]$$
$$+\beta(1-\delta)\left[\eta\mathbb{I}_{\{z'\geq\hat{z}_{0t+1}\}}\int_{-\infty}^{\infty} r_{mt+1}\left(z''\right) f\left(z''|z'\right)dz'' + \left(\mathbb{I}_{\{z'<\hat{z}_{0t+1}\}} + (1-\eta)\mathbb{I}_{\{z'\geq\hat{z}_{0t+1}\}}\right)\int_{-\infty}^{\infty} r_{dt+1}\left(z''\right) f\left(z\right.\right.$$
$$r_{mt}\left(z'\right) = \beta\lambda_{t+1}\left[(1-\alpha-\theta)Z_{mt+1}^{-\alpha-\theta}e^{\sigma_u^2}e^{z'}L_{mt+1}^{\alpha}\left(n^{1/\sigma}D_{mt+1}^{\frac{\sigma-1}{\sigma}} + \left(n^*\right)^{1/\sigma}M_{t+1}^{\frac{\sigma-1}{\sigma}}\right)^{\theta\frac{\sigma}{\sigma-1}} - \phi_1\mathbb{I}_{\{z'\geq\hat{z}_{1t+1}\}}\right]$$
$$+\beta(1-\delta)\left[\mathbb{I}_{\{z'\geq\hat{z}_{1t+1}\}}\int_{-\infty}^{\infty} r_{mt+1}\left(z''\right) f\left(z''|z'\right)dz'' + \mathbb{I}_{\{z'<\hat{z}_{1t+1}\}}\int_{-\infty}^{\infty} r_{dt+1}\left(z''\right) f\left(z''|z'\right)dz''\right]$$

6.2 Computational method

To solve the steady state and the transition path following a permanent change in p, I solve the social planner's problem, by approximating the distributions μ_d and μ_m by their values on a finely spaced grid. This is feasible for the steady state and deterministic path, but infeasible for solving the model subject to fluctuations in p_t.

I solve the model with fluctuations in p_t by adapting the Krusell and Smith method, by proxying the endogenous distributions μ_d and μ_m with a state variable of finite dimension, and approximating the aggregate variables in plants' decision problems with log-linear functions of the state. Khan and Thomas and Ruhl are examples of models with heterogeneity in production that use similar methods. The algorithm is as follows.

1. Select a finite set of moments to summarize the distributions μ_d and μ_m. Given how

these distributions enter the aggregate feasibility conditions, I use the two moments $Z = (Z_d, Z_m)$ defined by:

$$
\begin{aligned}
Z_d &= e^{\sigma_u^2} \int_{-\infty}^{\infty} e^z \mu_d(z)\, dz \\
Z_m &= e^{\sigma_u^2} \int_{-\infty}^{\infty} e^z \mu_m(z)\, dz
\end{aligned}
$$

2. Guess a set of coefficients in the approximate laws of motion for $H(p, Z) = (Z_d'(p, Z), Z_m'(p, Z))$ and $C(p, Z)$:

$$
\begin{aligned}
\log Z_d'(p, Z) &= b_{d0}^0 + b_{dp}^0 \log p + b_{dd}^0 \log Z_d + b_{dm}^0 \log Z_m \\
\log Z_m'(p, Z) &= b_{m0}^0 + b_{mp}^0 \log p + b_{md}^0 \log Z_d + b_{mm}^0 \log Z_m \\
\log C(p, Z) &= b_{C0}^0 + b_{Cp}^0 \log p + b_{Cd}^0 \log Z_d + b_{Cm}^0 \log Z_m
\end{aligned}
$$

   Denote these coefficients (b_d^0, b_m^0, b_C^0), where $b_i^0 = \left(b_{i0}^0, b_{ip}^0, b_{id}^0, b_{im}^0\right)$ for each $i = d, m, C$. With these laws of motion, the equilibrium wage $w(p, Z)$ can be explicitly calculated using the labor market clearing condition, evaluated at the moments Z_d and Z_m.

3. Solve the plants' problems by value function iteration on a grid of values for (z, p, Z_d, Z_m). I discretize z and p using Rouwenhorst's method, and Z_d and Z_m lie in an equally spaced grid centered around their steady state values. I use bilinear interpolation in the (Z_d, Z_m) dimensions to evaluate the future value functions off the grid.

4. Simulate a time series $\{p_t\}_{t=0}^T$ starting from the steady state $\bar{p}$. Starting from the steady state distributions $\bar{\mu}_d(z)$ and $\bar{\mu}_m(z)$, solve for sequences of equilibrium variables, $\left\{\hat{z}_{mt}, \hat{z}_{0t}, \hat{z}_{1t}, C_t, w_t, X_t, \mu_{dt+1}(z), \mu_{mt+1}(z), L_{dt}, D_{dt}, L_{mt}, D_{mt}, M_t, Z_{dt}, Z_{mt}\right\}_{t=0}^T$ using the system of equations,

$$
\begin{aligned}
\mu_{dt+1}(z') &= (1-\delta)\left[\int_{-\infty}^{\hat{z}_{0t}} \mu_{dt}(z) f(z'|z)\, dz + (1-\eta)\int_{\hat{z}_{0t}}^{\infty} \mu_{dt}(z) f(z'|z)\, dz + \int_{-\infty}^{\hat{z}_{1t}} \mu_{mt}(z) f(z'|z)\, dz\right. \\
&\quad + X_t \int_{-\infty}^{\hat{z}_{mt}} g(z) f(z'|z)\, dz
\end{aligned}
$$

$$
\mu_{mt+1}(z') = (1-\delta)\left[\eta \int_{\hat{z}_{0t}}^{\infty} \mu_{dt}(z) f(z'|z)\, dz + \int_{\hat{z}_{1t}}^{\infty} \mu_{mt}(z) f(z'|z)\, dz\right] + X_t \int_{\hat{z}_{mt}}^{\infty} g(z) f(z'|z)\, dz
$$

$$
L_{dt} + L_{mt} = 1
$$

$$
\begin{aligned}
& Z_{dt}^{1-\alpha-\theta} L_{dt}^{\alpha} n^{\frac{\theta}{\sigma-1}} D_{dt}^{\theta} + Z_{mt}^{1-\alpha-\theta} L_{mt}^{\alpha} \left(n^{1/\sigma} D_{mt}^{\frac{\sigma-1}{\sigma}} + (n^{*})^{1/\sigma} M_t^{\frac{\sigma-1}{\sigma}} \right)^{\theta \frac{\sigma}{\sigma-1}} \\
= \quad & C_t + D_{dt} + D_{mt} + p_t M_t + \phi_0 \eta \int_{\hat{z}_{0t}}^{\infty} \mu_{dt}(z)\, dz + \phi_1 \int_{\hat{z}_{0t}}^{\infty} \mu_{mt}(z)\, dz + X_t \left[\kappa_e + (1 - G(\hat{z}_{mt}))\, \phi_0 \right]
\end{aligned}
$$

$$
\begin{aligned}
Z_{dt} &= e^{\sigma_u^2/2} \int_{-\infty}^{\infty} e^{z} \mu_{dt}(z)\, dz \\
Z_{mt} &= e^{\sigma_u^2/2} \int_{-\infty}^{\infty} e^{z} \mu_{mt}(z)\, dz
\end{aligned}
$$

$$
L_{dt} = Z_{dt} \left(n^{\frac{\theta}{\sigma-1}} \theta^{\theta} \left(\frac{w_t}{\alpha} \right)^{\theta-1} \right)^{1/(1-\alpha-\theta)}
$$

$$
D_{dt} = w_t \frac{\theta}{\alpha} L_{dt}
$$

$$
L_{mt} = Z_{mt} \left(\left(\frac{w_t}{\alpha} \right)^{\theta-1} \theta^{\theta} n^{\frac{\theta}{\sigma-1}} \left(1 + \left(\frac{n^{*}}{n} \right) p_t^{1-\sigma} \right)^{\frac{\theta}{\sigma-1}} \right)^{1/(1-\alpha-\theta)}
$$

$$
M_t = p_t^{-\sigma} \frac{n^{*}}{n} D_{mt}
$$

$$
D_{mt} = \frac{w_t}{\alpha} \frac{\theta}{1 + \frac{n^{*}}{n} p_t^{1-\sigma}} L_{mt}
$$

$$
\begin{aligned}
C_t^{-\nu} \kappa_m &= \beta \int \int \left[V_m(z', p', Z_{t+1}) - V_d(z', p', Z_{t+1}) \right] f_z(z' | \hat{z}_{mt})\, f_p(p' | p_t)\, dz' dp' \\
C_t^{-\nu} \phi_0 &= \beta (1-\delta) \int \int \left[V_m(z', p', Z_{t+1}) - V_d(z', p', Z_{t+1}) \right] f_z(z' | \hat{z}_{0t})\, f_p(p' | p_t)\, dz' dp' \\
C_t^{-\nu} \phi_1 &= \beta (1-\delta) \int \int \left[V_m(z', p', Z_{t+1}) - V_d(z', p', Z_{t+1}) \right] f_z(z' | \hat{z}_{1t})\, f_p(p' | p_t)\, dz' dp'
\end{aligned}
$$

$$
C_t^{-\nu} \kappa_e = \int V_e(z, p, Z_t)\, g(z)\, dz
$$

In this step, I use Gaussian quadrature to integrate μ_{dt} and μ_{mt}, and the probabilities associated with the discretized Markov chains for z and p to integrate the value functions.

5. From the simulated series, calculate new coefficients $(b_d^1), (b_m^1), (b_C^1)$ by linear regres-

sion,

$$\begin{aligned}
\log Z_{dt+1} &= b^1_{d0} + b^1_{dp} \log p_t + b^1_{dd} \log Z_{dt} + b^1_{dm} \log Z_{mt} \\
\log Z_{mt+1} &= b^1_{m0} + b^1_{mp} \log p_t + b^1_{md} \log Z_{dt} + b^1_{mm} \log Z_{mt} \\
\log C_t &= b^1_{C0} + b^1_{Cp} \log p_t + b^1_{Cd} \log Z_{dt} + b^1_{Cm} \log Z_{mt}
\end{aligned}$$

6. If $\max \{|b^1_d - b^0_d|, |b^1_m - b^0_m|, |b^1_C - b^0_C|\} < 10^{-5}$, stop. Otherwise set $b^0_i = b^1_i$ for each $i = d, m, C$, and go back to step 3.

The R^2's of the three converged forecasting rules in each of the models are: for $\eta = 1$, 0.9500, 0.9626, and 0.9871; and for $\eta < 1$, 0.9881, 0.9948, and 0.9991.

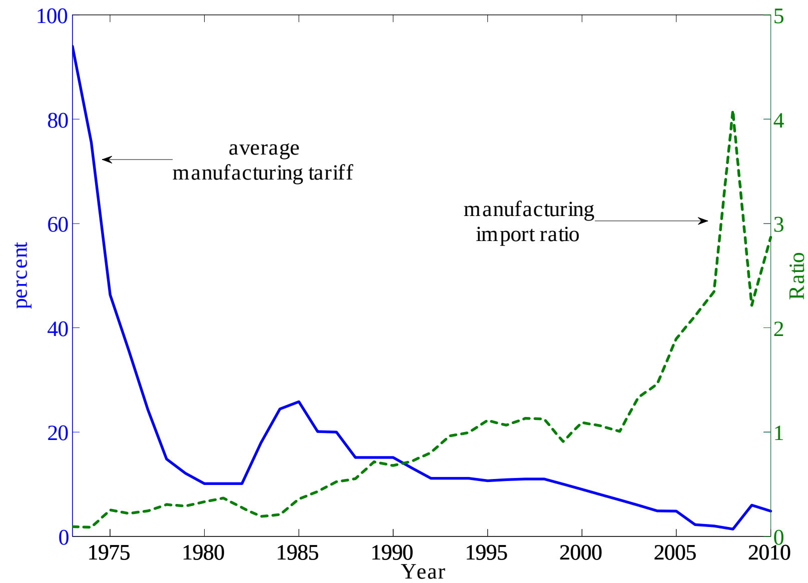

Figure 1: Average tariffs and import ratio in Chilean manufacturing.

Table 1: Imported Intermediate Inputs in World Trade

Country	$\frac{\text{Intermediates}}{\text{Merchandise Imports}}$	Year
Australia	0.35	1994-5
Brazil	0.52	1996
Canada	0.39	1997
China	0.62	1997
Czech Republic	0.49	1995
Denmark	0.35	1997
Finland	0.56	1995
France	0.47	1995
Germany	0.43	1995
Greece	0.27	1994
Hungary	0.57	1998
Italy	0.51	1992
Japan	0.50	1995
Korea	0.63	1995
Netherlands	0.34	1995
Norway	0.32	1997
Poland	0.49	1995
Spain	0.52	1995
United Kingdom	0.37	1998
United States	0.34	1997

Source: OECD Input-Output Tables. Ratio reported is the fraction of manufacturing, mining, and agricultural imports used as intermediate inputs by manufacturing, mining, and agricultural industries.

Table 2: Short-run Armington Elasticity in Chilean Manufacturing

Regression	
constant	0.738^*
	(0.167)
relative price of imports, p_t	-2.898^*
	(0.304)
R^2	0.655
Volatility ratio	3.582

* denotes significance at 1%. Data are as described in text.

Table 3: Cross-section Plant Characteristics

	Importers (%)	Size Ratio
1979	22.7	3.94
1980	22.5	3.55
1981	24.8	3.29
1982	22.6	3.06
1983	23.8	3.36
1984	24.0	3.34
1985	25.0	3.30
1986	25.4	3.24
1987	24.4	3.14
1988	23.7	2.99
1989	21.2	3.11
1990	20.4	2.96
1991	21.2	2.86
1992	23.4	3.09
1993	24.3	3.06
1994	26.4	3.12
1995	23.9	2.99
1996	24.2	3.16
avg, 79-96	**23.6**	**3.20**
avg, 86-96	**23.5**	**3.07**

Source: Chile's *Encuesta Nacional Industrial Anual.*
Size ratio is average employment of importing plants divided by average employment of non-importing plants.

Table 4: Decomposition of Aggregate Import Share, Chile 1979-86

	% of Total Change in Import Share			
Time period	Within	Between	Switch	Net entry
1-year changes	75.4	16.9	5.9	1.8
5-year changes	64.0	14.5	13.6	7.9

Source: Chile's *Encuesta Nacional Industrial Anual.*
See text and equation (3) for column definitions.

Table 5: Calibration

Parameter	Role	Value	Chosen to Match
β	discount factor	0.96	annual $r = 0.04$
ν	intertemporal elasticity	2.00	standard value
α	wN / gross output	0.21	average labor share, rescaled
θ	intermediates / gross output	0.64	average intermediate share, rescaled
κ_e	cost of entry	0.10	normalization
ρ_p	persistence of agg. shocks	0.895	Chile relative import price data
η_ε	std. dev. of agg. shocks	0.028	Chile relative import price data
σ	within-plant elasticity	2.4	equation (10)
$\bar{p}$	steady state import price	1.771	31% plant-level import share
ρ_z	persistence of plant-level shocks	0.926	coefficient in regression (11)
δ	exit rate	0.036	average exit rate 3.6%
Jointly calibrated parameters for model with no switching friction ($\eta = 1$)			
σ_u	std. dev. of transitory shocks	0.385	0.54 residual variance in regression (11)
σ_z	std. dev. of persistent shocks	0.129	4.98 importer/nonimporter size ratio
κ_m	fixed cost for entrant	0.0151	23% of plants importing
ϕ_0	fixed cost for nonimporter	0.0169	5.8% nonimporter → importer switch rate
ϕ_1	fixed cost for importer	0.0162	18.8% importer → nonimporter switch rate
Jointly calibrated parameters for model with no switching friction			
σ_u	std. dev. of transitory shocks	0.363	0.54 residual variance in regression (11)
σ_z	std. dev. of persistent shocks	0.217	4.98 importer/nonimporter size ratio
κ_m	fixed cost for entrant	0.0197	23% of plants importing
ϕ_0	fixed cost for nonimporter	0.0038	5.8% nonimporter → importer switch rate
ϕ_1	fixed cost for importer	0.0143	18.8% importer → nonimporter switch rate
η	switching friction	0.060	New / existing importer average size 0.64

Table 6: Model: Decomposition of Short-Run Fluctuations

	Short-run Armington elasticity		Decomposition (% of change in Import Share)			
	regression coefficient	volatility ratio	Within	Between	Switch	Net Entry
Model with $\eta = 1$	4.66	4.79	29.63	13.54	53.48	3.36
Model with $\eta < 1$	3.65	3.69	43.59	26.54	23.24	6.64

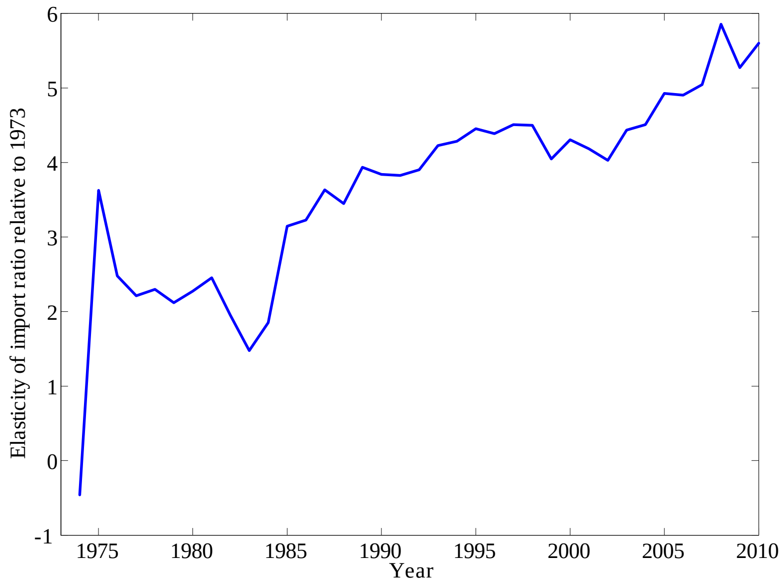

Figure 2: Time-varying Armington elasticity calculated from growth in import share relative to change in tariff, from 1973.

Table 7: Dynamics of Trade Liberalization

	Percent growth rate					
	Model with $\eta = 1$			Model with $\eta < 1$		
	1 year	10 years	new ss	1 year	10 years	new ss
import ratio $\frac{M}{D}$	34.90	68.94	73.63	34.91	58.77	66.52
import share $\frac{M}{M+D}$	26.60	49.57	52.53	26.61	42.99	48.01
Armington elasticity	3.49	6.89	7.36	3.49	5.88	6.65
	Welfare gains, %					
	Model with $\eta = 1$	Model with $\eta < 1$				
across steady states (λ_S)	4.03	4.57				
including transition (λ_T)	5.94	5.62				