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TRADE ADJUSTMENT AND PRODUCTIVITY IN LARGE CRISES

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Trade Adjustment and Productivity in Large Crises  
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### **ABSTRACT**

We empirically characterize the mechanics of trade adjustment during the Argentine crisis using detailed transaction-level customs data covering the universe of import transactions during 1996-2008. Though imports collapsed by nearly 70 percent from 2000-2002, the entry and exit of firms or products at the country level (the "extensive margin") played a small role in this adjustment. By contrast, the within-firm churning of inputs (the "sub-extensive margin") played a sizeable role, and we highlight significant heterogeneity in how firms adjusted their import mix. Motivated by these facts, we build a model of trade in intermediate inputs with heterogeneous firms, fixed import costs, and roundabout production to evaluate the channels through which a collapse in imports affects productivity. Import demand is non-homothetic and therefore the implications for productivity depend on the details of individual firm adjustments and cannot be summarized by the change in the aggregate import share. We simulate the model to discuss quantitatively these mechanisms in the context of an imported input cost shock that produces a significant productivity decline

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# 1 Introduction

Large crises such as the Mexican crisis in 1994–1995, the East Asian crisis in 1997–1998, and the Argentine crisis in 2001–2002 are characterized by large exchange rate depreciations and collapses in imports. The dollar value of Argentina’s imports, for instance, dropped by 69 percent between 2000 and 2002. A second feature of these episodes is the large decline in real GDP and total factor productivity (TFP). Sandleris and Wright (2011) document an 11 percent decline in TFP of continuing manufacturing plants in Argentina between 2000 and 2002.<sup>1</sup>

In this paper we do two things. First, we empirically characterize the mechanics of trade adjustment at the firm and product level during the Argentine crisis. Our analysis makes use of detailed firm-level customs data covering the universe of import transactions for Argentina during 1996–2008, a period that includes a dramatic nominal exchange rate depreciation and trade balance reversal. Second, motivated by the empirical evidence, we develop a model of trade in intermediate inputs with heterogeneous firms, fixed import costs, and roundabout production to evaluate the channels through which the collapse in imports affects a welfare relevant measure of productivity in manufacturing.

The trade literature includes many empirical analyses of the impact that permanent shocks such as trade liberalizations have on the extensive margins of adjustment—either via changing the allocation of resources across firms (Melitz, 2003) or via changing product varieties (Krugman, 1980). This paper empirically evaluates how important these various forms of extensive margin adjustment are at business cycle frequencies, particularly in the context of a large crisis.

We establish the following facts about the collapse in imports during Argentina’s crisis. First, the number of firms that exit the import market is large, but when weighted by value these exits explain a small share of the total decline in imports. The number of importing firms dropped from over 15,000 to less than 7,000 over the first four quarters of the crisis and did not return to its pre-crisis level for about five years. However, the net contribution of firm entry and exit explains less than 8 percentage points of the 69 percent decline in imports

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<sup>1</sup>Meza and Quintin (2006) document that TFP declined by 8.6 percent in Mexico in 1994, by 15.1 percent in Thailand, and by 7.1 percent in South Korea during the East Asian crisis.

during the crisis. The pattern is similar for the number of imported product varieties. The number of distinct 10-digit Harmonized Tariff Schedule (HTS) product codes imported dropped from approximately 13,000 to 10,000 over the same period and also took about five years to recover. Product entry and exit, though, only explains between 0 and 15 percentage points of the decline depending on the definition used. These findings hold when looking at the quarterly or annual frequency, when looking at normal times as well as during the crisis and recovery, and when separately considering each end-use category.

The reason for this result is the high degree of concentration in international trade among a small number of key firms and sectors. The largest 5 percent of importing firms contribute approximately 85 percent of Argentina's imports and generally do not change their import status after the crisis.<sup>2</sup> Similarly, the largest 5 percent of imported 6-digit HTS categories together account for about 60 percent of imports and are rarely dropped from the set of aggregate imports.

However, trade in most countries, including Argentina, consists primarily of intermediate inputs. It is therefore important to examine what happens to the bundle of imports at the firm level as opposed to the country level. Even if a particular input variety continues to be imported into the country, it may still be the case that several firms stop importing it and thereby experience changes in their unit costs of production.

As an illustration, Figure 1 shows sample import activity for two large Argentine industrial manufacturing companies, both among Argentina's top 50 importers: BGH S.A. and Siderca S.A.I.C. Both companies imported heavily in key intermediate input categories before the crisis, but stopped importing these inputs during the crisis.<sup>3</sup> These products disappeared from the import bundle of these two companies, but this absence would not be observable in aggregate data because other Argentine firms continued to make purchases in all of these categories during the same period. Further, while these two companies stopped

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<sup>2</sup>As discussed below, we can rule out the possibility that the largest importers are simply huge distributors or import/export brokers.

<sup>3</sup>BGH imported industrial cooling fans and anti-vibration materials, largely from Motorola, during most quarters in 2000 and 2001. With the onset of the crisis and after the exchange rate shock, imports of those goods dropped to zero for six quarters, only to return in late 2003. Siderca, after importing more than \$2 million of tools for steel-cutting lathes in 2001 and spending more than \$200,000 on imported tools for aluminum smelting and mixing, exited those import markets completely in 2002 and early 2003. By late 2003, they returned to importing in those sectors and by 2004 spent almost \$9 million on those imported goods.

importing these particular inputs, neither company would appear in aggregate extensive margin calculations because they continued importing at least some other product during the crisis. More generally we document that many imported products which are dropped by a clear majority of importers are not considered to be dropped varieties at the aggregate level because a minority of firms continue to import them. A product only contributes to the extensive margin at the country level if all importers of that variety happen to decide to stop importing it, something unlikely to happen for goods with large import volumes.

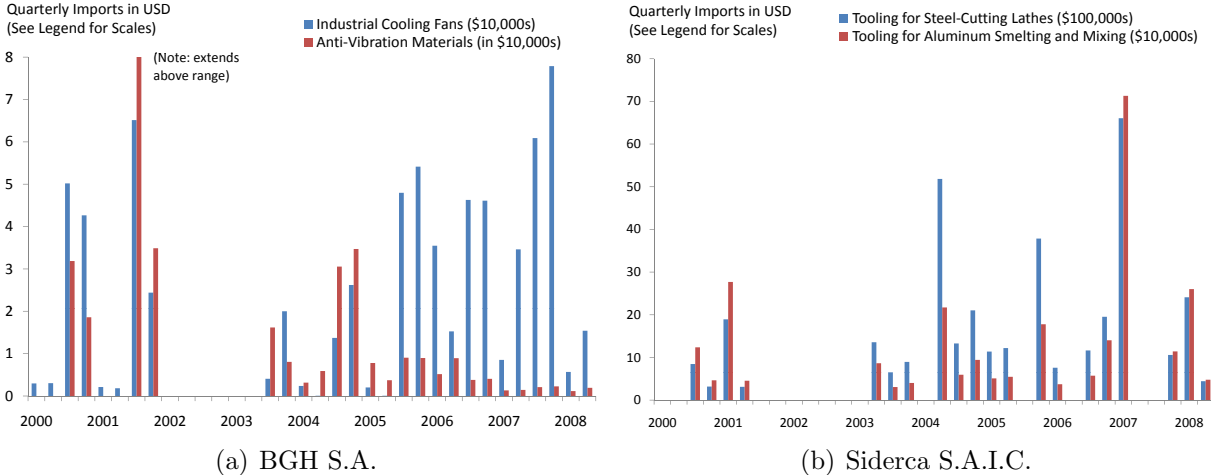


Figure 1: Sample Quarterly Product Imports for Two Large Argentine Firms

This observation leads to our second empirical finding: Within-firm changes in the mix of imported varieties and supplier countries, regardless of whether other importers drop those same varieties, play a significant role in trade adjustment. This within-firm extensive margin, or “sub-extensive” margin, explains up to 45 percent of the 69 percent decline in imports between 2000 and 2002.

Third, we find that the way importers adjust their imports varies with the size of the firm. The extensive margin, when a firm exits trade entirely, is the most prevalent margin of external adjustment for the smallest firms. Among continuing importers, the sub-extensive margin becomes less important as the size of the importer grows. The largest firms adjust primarily by reducing—but not dropping—their imports of particular products, which we call the sub-intensive margin. As a result, the largest pre-crisis importers exhibited smaller percentage declines in their import volumes.

Fourth, we estimate the impact of sub-extensive margin adjustment on unit costs under the assumption of a constant elasticity of substitution (CES) production function. If inputs are imperfect substitutes, a drop in the number of imported varieties used will raise firms' unit costs of production. In the absence of firm-level data, one would conclude that the impact on the unit cost of an import bundle arising from dropped varieties is close to zero. Our firm-level data, by contrast, imply that this unit cost increased by up to 13 percentage points for a typical importer due to the sub-extensive margin.

Motivated by these empirical facts, we build a simple partial equilibrium model of a monopolistically competitive industry (manufacturing) that imports intermediate inputs. The firms in the industry differ in terms of their technology, pay fixed costs for importing input varieties, and use each other's output as inputs giving rise to roundabout production. The intermediate input aggregator in the production function displays a "love of variety" feature with inputs being imperfectly substitutable as in Ethier (1982). We introduce an imported input cost shock and study the implications for a welfare relevant measure of productivity.

We start by using the model to clarify why imperfect competition implies that, in contrast to findings in the previous literature, terms of trade shocks have a first-order effect on productivity. We follow Basu and Fernald (2002) and calculate productivity as the Solow residual with value added factor share weights that need not sum to one, the standard welfare relevant measure. We assume imperfect competition in the product market, which implies that the marginal rate of transformation of factors in the production function exceeds their marginal rate of substitution in the utility function. As a result, shocks that reduce the scale of a firm's production have a first order effect on productivity even when technology is unchanged, an insight that goes back to Hall (1988, 1990).

An imported input cost shock increases the unit cost of production because domestic and imported inputs are imperfectly substitutable. Roundabout production amplifies the shock because the increase in one firm's costs results in higher output prices which imply higher input prices for other firms. These cost increases can reduce the relative demand for output of sectors that rely on imported inputs (manufacturing) relative to those that do not (like services) generating a decline in the scale of production of manufacturing and

therefore productivity. The presence of intermediate inputs can render large the impact on productivity, even when markups are small but non-zero.

Next, we use the theory to focus on three repercussions for productivity of our empirical findings on the sub-extensive margin. First, in the presence of fixed costs, firms adjust input use both along the intensive and sub-extensive margins by dropping imported varieties. The elasticity of imports to the shock is therefore bigger. Moreover, the change in imported input varieties generates an increase in unit costs above and beyond that implied by the shock, along the lines of Halpern, Koren, and Szeidl (2009). These two forces work in the direction of generating a greater decline in productivity. On the other hand, there is also a force pushing productivity in the opposite direction, as less labor is used to pay for fixed costs. Second, we show that the model with sub-extensive margin generates non-homothetic import demand, with larger firms importing a larger set of varieties. This implies the impact on aggregate productivity will depend on the details of the individual firms' responses to the shock and cannot be summarized by the change in the aggregate import share. Differences in sub-extensive margin adjustment imply differences in the change in firms' unit costs, leading to changes in firms' market shares. The change in aggregate import share does not equal the import-weighted sum of changes in firm-level import shares. Third, our theory clarifies how the sub-extensive margin implies mismeasurement of productivity. Standard national accounting practices, including those used in Argentina, use "matched-model" price indices that ignore changes in varieties. If production is CES, this practice would underestimate the increase in input prices, thereby increasing imputed real intermediate input use and decreasing measured productivity. This mismeasurement is only economically meaningful when taking into account the sub-extensive margin.

We then calibrate the input cost shock to match our empirical findings for Argentina and simulate the model to evaluate quantitatively the combined impact of these channels relative to standard models that exclude sub-extensive margin adjustment. The effects of the shock are sizable with productivity declining by over 5 percentage points. In the absence of firm-level data, one might ignore heterogeneity in trade responses across firms and conclude that dropped input varieties were not an important part of adjustment. We therefore compare our benchmark simulation to a calibration of our model without fixed costs, as one might choose

if guided only by aggregate data. We show that the model with active sub-extensive margin adjustment exhibits a productivity decline nearly 30 percent larger, or 1.2 percentage point more, than that in the equivalent specification without a sub-extensive margin and exposed to the same shock. If we additionally take into account the mismeasurement implied by dropped varieties, the sub-extensive margin generates a measured productivity decline more than 50 percent larger than the equivalent model without a sub-extensive margin. We also consider simulations without roundabout production and find the productivity decline is about one half the size of the benchmark case.

There clearly were many other negative shocks that impacted productivity during the Argentine crisis. The time-series pattern for TFP, imported input use, and sub-extensive margin adjustments, however, do offer corroboration that the mechanisms highlighted in our paper may well have been salient for TFP in Argentina over this period. The share of input spending on imports and the importance of the within-firm dropping of import varieties moved together with TFP both in the period of economic decline and recovery. We focus on Argentina due to the availability of long-dated and detailed transaction-level data surrounding an acute sudden stop and exchange rate shock. Our analysis, however, has broader relevance and can help answer the question of how trade adjusts and the impact this adjustment has on the macroeconomy during business cycles and crisis episodes.

## Related Literature

This paper relates to many literatures. First, it relates to the literature that empirically characterizes the margins of trade adjustment and is consistent with the findings of Bernard, Jensen, and Schott (2009) and Bernard, Jensen, Redding, and Schott (2009) who use U.S. data to document that the firm and aggregate product extensive margins are small while the sub-extensive margin is large.<sup>4</sup> Distinct from their analysis we focus on a dramatically larger trade adjustment episode using the Argentine experience and specifically evaluate the implications of these findings for productivity.

Second, it is related to the literature that evaluates the impact of imported intermediate inputs on productivity. See, for instance, Amiti and Konings (2007) and Goldberg,

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<sup>4</sup>Also see di Giovanni and Levchenko (2009) who argue that this finding can imply the welfare impact of high entry costs on production is small.



Khandelwal, Pauvcnik, and Topalova (2009) for the impact of liberalization and increased trade in Indonesia and India, respectively. Halpern, Koren, and Szeidl (2009) use Hungarian firm-level data to document gains from improved access to imports when these imports are imperfectly substitutable for domestic inputs at the firm level. Their measure of productivity gains is the decline in firms' unit costs (marginal costs) of production arising through the sub-extensive margin. We evaluate the impact on a welfare relevant measure of productivity that differs from changes in unit cost, and we study the implications for aggregate productivity of the various margins of trade adjustment.<sup>5</sup>

Third, our work relates to research linking terms of trade shocks to productivity and welfare. Kehoe and Ruhl (2008) argue that, under perfect competition, terms of trade movements have no first-order effects on productivity. This is not the case in our environment since firms are price setters who charge markups. As is well known from Hall (1990) and Basu and Fernald (2002), in the presence of markups, variations in the use of primary factors and in the intensity of use of intermediate inputs will have a first order impact on productivity.<sup>6</sup>

Arkolakis, Costinot, and Rodriguez-Clare (2011) point out that in a broad class of models, all that is needed to evaluate trade-induced changes in welfare is the observed change in aggregate trade shares and an appropriate elasticity. The specifics of firm-level adjustment do not matter. On the contrary, in our setting the full distribution of import shares are needed to evaluate aggregate effects on welfare and productivity. There are economically meaningful differences between an environment with and without fixed costs even when they both generate the same change in aggregate import shares.

Lastly, our work is related to Sandleris and Wright (2011) and Neumeyer and Sandleris

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<sup>5</sup>Broda, Greenfield, and Weinstein (2006) also evaluate the gains in unit costs in many countries brought about by increased input varieties at the sector level from 1994–2003. Feenstra, Mandel, Reinsdorf, and Slaughter (2009) consider the possibility that unmeasured gains in the terms of trade around 1995 contributed to the measured productivity acceleration in the United States. Among other channels, they highlight the failure of conventional price indices to account for the increase in varieties of traded information technology products. Burstein, Eichenbaum, and Rebelo (2005) note, also in the context of the Argentine crisis, that changes in price indices may be biased downward during large devaluations because households substitute toward lower-quality goods. Burstein and Cravino (2010) evaluate how trade liberalizations lead to increases in real GDP if price indices partially capture reductions in tariffs.

<sup>6</sup>Ghironi and Melitz (2005) highlight the impact of firm entry and exit decisions on business cycle moments. Mendoza and Yue (2009) explore quantitatively the impact of imperfect substitutability between domestic and imported intermediate inputs coupled with a worsening of the terms of trade on the amplification of financial shocks.

(2010), which explore the impact of misallocation on TFP during the Argentine crisis and find that it plays an important role. We view our explanation for the productivity decline as complementary to the one proposed in these other papers.

## 2 Data

After eight years of growth averaging just under 6 percent per year, Argentina entered a recession in 1999, with GDP, consumption, and investment all declining in real terms. The recession worsened sharply in 2001:Q4, with real GDP ending 2002:Q1 more than 16 percent below its level a year earlier. A large banking and currency crisis ensued and the Argentine peso rapidly depreciated by nearly 200 percent relative to the U.S. dollar. Argentina’s dollar-denominated import price index was relatively stable, implying an upward spike in peso-denominated import prices that resulted in a 69 percent drop in dollar imports from 2000 to 2002.<sup>7</sup>

We now describe the data we use on firms and trade transactions during the Argentine crisis. We bring together three datasets, starting with two datasets containing Argentine customs data provided by private vendors called Datamyne and Nosis. We combine these data with operating and financial information on the largest Argentine firms, available from the Capital IQ database.

### 2.1 Detailed Trade Data from Customs

Our data are collected from import and export shipping manifests by the customs agency in Argentina and are publicly released. The data vary somewhat in coverage over time, but give detailed information for each trade shipment, generally including the name of the importer or exporter, the date of declaration, the source or destination country, the quantity, weight, price, and value of the good, along with detailed information at levels at least as disaggregated as the 10-digit HTS classification.<sup>8</sup> We obtained most of our data from

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<sup>7</sup>There was a secular shift in import market shares away from U.S. and toward Brazilian exporters from 1999–2006, but the crisis of 2001–2002 itself did not have an obvious impact on the import shares of Argentina’s trading partners.

<sup>8</sup>Argentina additionally adds its own code with an 11th digit and a letter (as the 12th character, A-Z) to the HTS classification, so these products can often be easily distinguished at a 12-digit level.

Datamyne, a private provider of these trade statistics that receives a daily electronic feed from the customs authorities.<sup>9</sup> Subject to the few exceptions detailed below, we obtained data on all trade in goods for Argentina for the 1996–2008 period. We now describe the imports and exports data in turn.

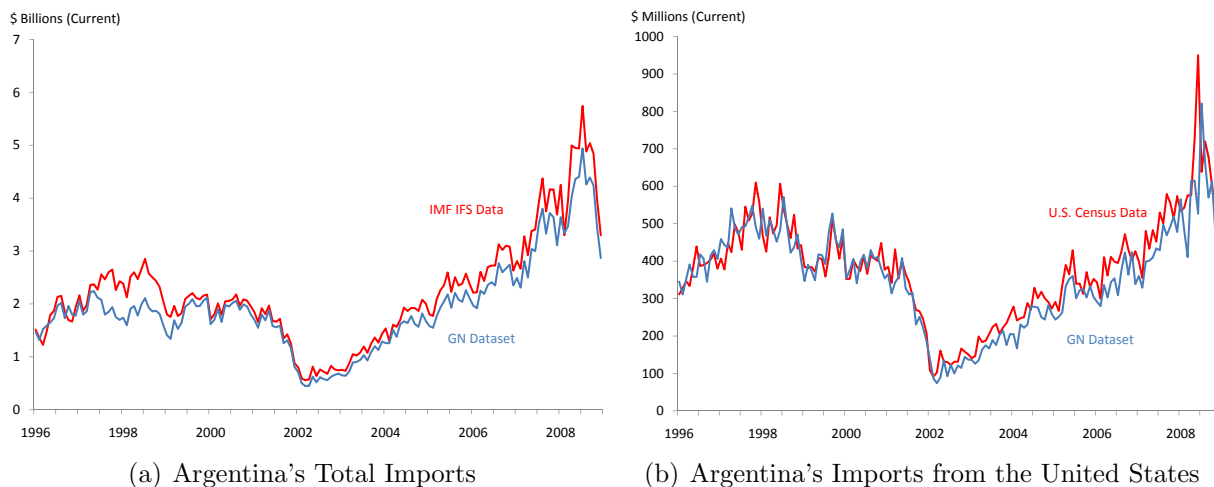


Figure 2: Our Dataset Compared to Other Sources

Figure 2(a) compares the total value of Argentina’s imports in our dataset with the value reported in the International Financial Statistics database provided by the International Monetary Fund. The data line up extremely well, including at high frequency, with the only exception being a period from mid-1997 to early 1999 when our data miss about one-third of the imports because Argentine customs did not provide it to Datamyne. Further, we compare reporting on these flows to their counterparts in data collected by the Foreign Trade Division of the U.S. Census Bureau. Figure 2(b) demonstrates that though some discrepancies clearly exist, the basic patterns captured in the U.S. bilateral trade data are also reflected in our micro dataset.

Economy-wide, imports come from more than 100 countries, include more than 15,000 HTS codes, and often reflect more than 100,000 different country and product code combinations. The smallest importers may trade with only one partner, but some importers are

<sup>9</sup>Though Datamyne does not add or edit any information on its own, it takes significant measures to ensure the information is fully and accurately transmitted from the customs authority. Moreover it is among the few such data providers that has received International Standards Organization (ISO) certification, reflecting the reliability of its quality control systems.

supplied by over 40 different countries and themselves import in nearly 900 categories. Table 1 lists these and related summary statistics for imports in 2000 and 2002.

	2000	2002
# of Importing Firms	25,138	13,980
# of Supplier Countries		
Economy-wide	135	130
Per Firm, median	2	1
Per Firm, maximum	44	36
# of Imported HTS Codes		
Economy-wide	17,333	15,831
Per Firm, median	5	4
Per Firm, maximum	899	733
# of Imported Country X HTS Combinations		
Economy-wide	115,724	80,781
Per Firm, median	6	4
Per Firm, maximum	2,067	2,176

Table 1: Import Summary Statistics

The Datamyne data include the equivalent information on export transactions from 1996–2008, though the exporter names are redacted from 2000 onward. This redaction was performed by Argentina’s customs authority and is not specific to the Datamyne data. To overcome this problem, we merge the data from Datamyne with another dataset covering the period subsequent to 2000 that we obtained from Nosis, a private vendor.<sup>10</sup> Unfortunately, the Nosis data omit firm identifiers for a large share of the transactions in 2000 and 2001, so we cannot do the same analyses for exports as we do for imports.<sup>11</sup>

<sup>10</sup>Nosis combines their own market knowledge with an algorithm that compares export transactions for the post-2000 period, when exporter names are not available, to earlier transactions that include the names in order to generate a “probable exporter.” For instance, if an export transaction in 2003 had similar port, HTS, volume, and destination information as several of BGH’s export transactions from the late 1990s, the algorithm would likely list BGH as the exporter in 2003. The Nosis database does not contain tax identification codes that we use as our firm identifiers so we hired data analysts to use text-matching software to link the two parts of our export data. We identify each firm by its CUIT, which is the company’s tax identification number. This is a more stable and reliable indicator of each firm than the “name” field, which is more prone, for example, to typographical errors.

<sup>11</sup>See Albornoz, Pardo, Corcos, and Ornelas (2010) for a related analysis of Argentine exports.

## 2.2 Capital IQ Database

We match the firm names in our trade data with the Capital IQ database so we can learn more about the importers themselves. Capital IQ contains operating and financial information on about 4,500 firms in Argentina, including public, private, domestic, and multinational firms. Our trade data include dramatically more firms, but given the concentration of trade and Capital IQ information among the largest firms, we are able to match firms accounting for 60–70 percent of Argentina’s imports.

Table 7 (found at the end of the paper) lists Argentina’s largest 50 importers for the period 1996–2008, along with their primary industry and primary sector, as reported in the Capital IQ database.<sup>12</sup> Seven of the largest eight importers, themselves responsible for a bit less than 10 percent of total imports in a typical year, are all Argentine subsidiaries of foreign automobile manufacturers. Outside of these seven, however, many industries are represented with no obvious concentrations or patterns. Though most of the companies are recognizably not trading firms or distributors, we formalize this analysis using data on the primary industry of importing firms. The monthly share of imports by firms with primary industry data that go to firms classified as “Distributors,” “Food Distributors,” “Healthcare Distributors,” “Technology Distributors,” or “Trading Companies and Distributors” ranges from about 3 to 8 percent. These percentages are fairly stable throughout the dataset.

## 3 Empirical Findings

In this section we report our main empirical findings. We show that the large decline in aggregate imports during the crisis is explained primarily by declines from continuing importers and has little to do with the entry and exit of firms into and out of import status. The adjustment in trade takes place within firms at what we call the sub-intensive and sub-extensive margins as firms both reduce the import value of each continuing variety and reduce the number of imported varieties. Firms typically differ, however, in their decisions of which varieties to drop, with one firm dropping a variety and another continuing to import

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<sup>12</sup>We exclude Argentina’s Central Bank, which is credited in the data with some import flows associated with its extension of trade financing. We had a research assistant fill in blank entries for companies’ primary sector and primary industry classifications.

that same item. As a result, our firm-level data reveal that the product extensive margin is an important source for adjustment, but an analysis of aggregate data would conclude it is insignificant.

Additionally, we show that the relative importance of the extensive, sub-extensive, and sub-intensive margins varies with firm size, and the import volumes of larger importers decline proportionately less than those of smaller importers. Finally, we show that if inputs are imperfect substitutes, within-firm sub-extensive margin adjustment impacts the unit cost of production for firms. Assuming a constant elasticity of substitution, we calculate that the unit cost of the typical import bundle increased up to 13 percentage points more than what one would infer based only on information contained in aggregate data. We describe in detail the findings below.

***Finding 1: Defined as the entry and exit of firms or the entry and exit of products at the country level, the “extensive margin” plays a small role in understanding trade adjustment during the crisis.***

Total dollar imports declined by 69 percent from 2000 to 2002. We first evaluate what fraction of this decline is explained by firm entry and exit into and out of import status and similarly what fraction is explained by the entry and exit of products into the import bundle. Figure 3 shows the number of importers and number of imported 10-digit HTS categories for 1996–2008, excluding the period in the late 1990s when the data are incomplete. We find that the number of firms that imported any goods in each quarter dropped by more than one-half and the number of imported product categories dropped by nearly one-fourth. However, in terms of volumes these entries and exits explain a small fraction of the decline in imports.

We can disaggregate the intensive margin from the importers’ margins of entry and exit as follows:

$$\frac{\Delta v_t}{v_{t-1}} = \underbrace{\left( \sum_{i \in \Psi_{t-1} \cap \Psi_t} \frac{v_{i,t} - v_{i,t-1}}{v_{t-1}} \right)}_{\text{Intensive Margin}} + \underbrace{\left( \sum_{i \in \Psi_t, i \notin \Psi_{t-1}} \frac{v_{i,t}}{v_{t-1}} - \sum_{i \in \Psi_{t-1}, i \notin \Psi_t} \frac{v_{i,t-1}}{v_{t-1}} \right)}_{\text{Extensive Margin}}, \quad (1)$$

where  $v_{i,t}$  is firm  $i$ ’s total (fob) spending on imports,  $\Psi_t$  is the set of all importing firms

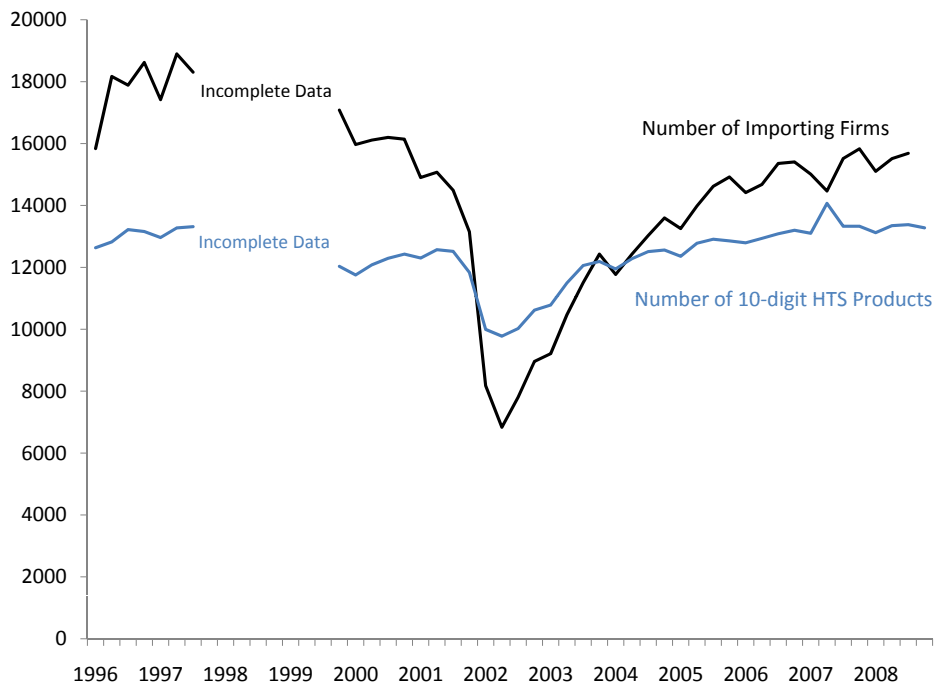
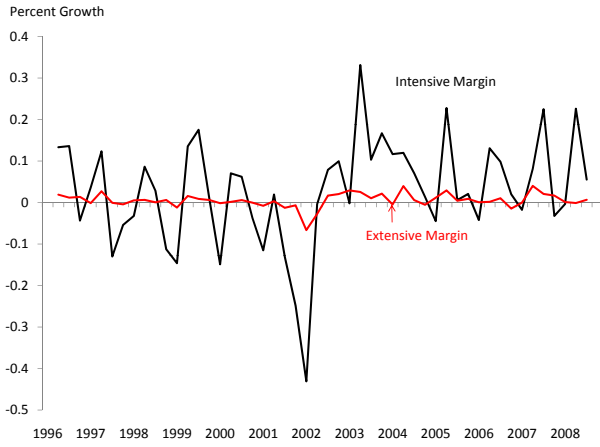


Figure 3: Number of Importing Firms and Products

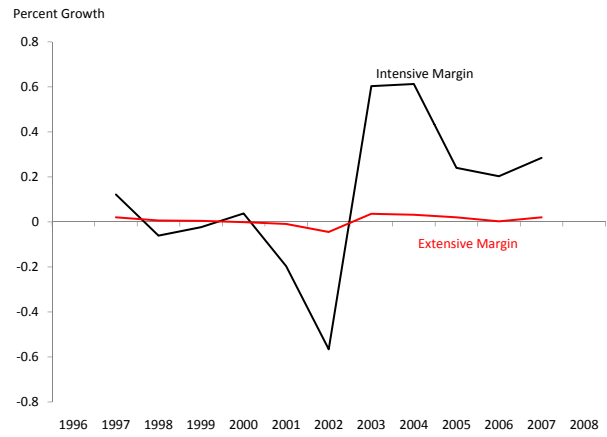
in period  $t$ ,  $v_t = \sum_{i \in \Psi_t} v_{i,t}$  are total imports in the economy, and  $\Delta v_t = v_t - v_{t-1}$ . The first term on the right hand side of Equation (1) is the intensive margin and captures the change in imports from continuing importers. The second term is the extensive margin and captures the value of imports from new importers net of the volume lost from those that stopped importing in period  $t$ .

Figures 4(a) and 4(b) show, for definitions of  $t$  as quarters and as years, the breakdown of aggregate movements in trade by intensive and extensive margins. Note that the sum of these lines equals the growth rate of aggregate imports. They plot the share of overall import growth *due to* each margin, not the growth *of* each margin, and therefore correspond to the economic significance of each type of adjustment. The plots demonstrate that the entry or exit of firms or products attribute only a small share of the change in the volume of imports. For example, the black line in Figure 4(b) dips to about -57 percent in 2002 while the red line reaches about -4 percent. This means that while overall imports declined by nearly 61 percent in 2002 compared to 2001, the vast majority came from the intensive margin.

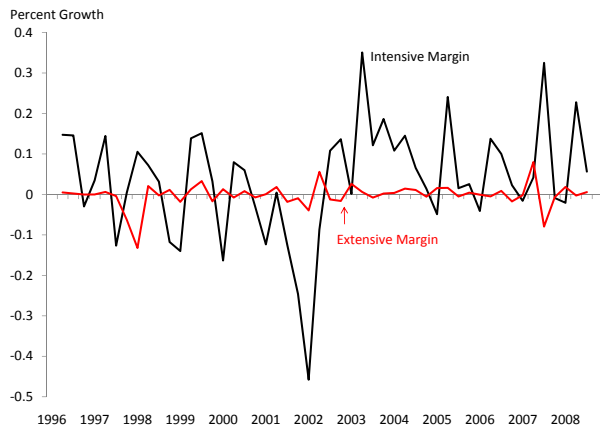
We can do the equivalent exercise for products, where we use the same disaggregation (1), but redefine  $\Psi_t$  to be the set of all imported product categories in period  $t$ . Figures



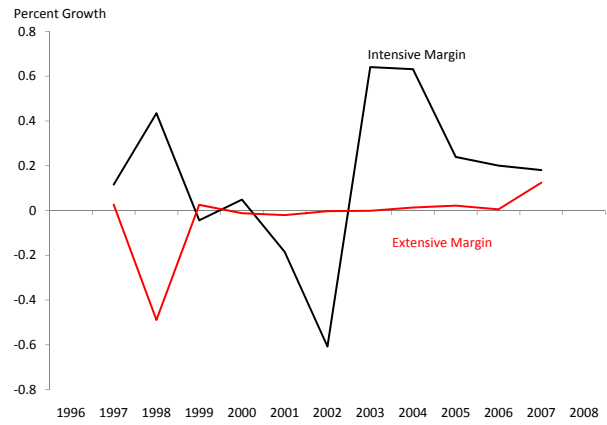
(a) Importing Firm (Quarterly)



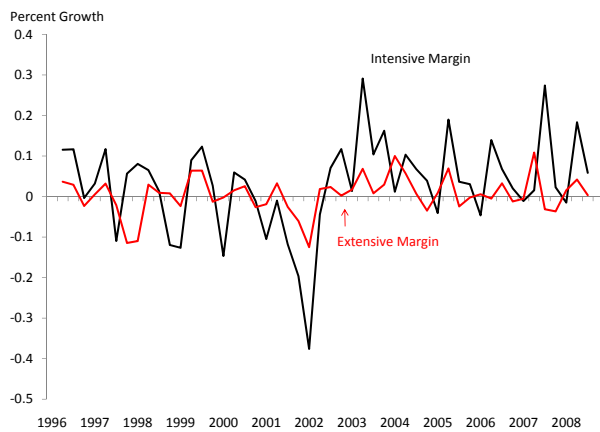
(b) Importing Firm (Annual)



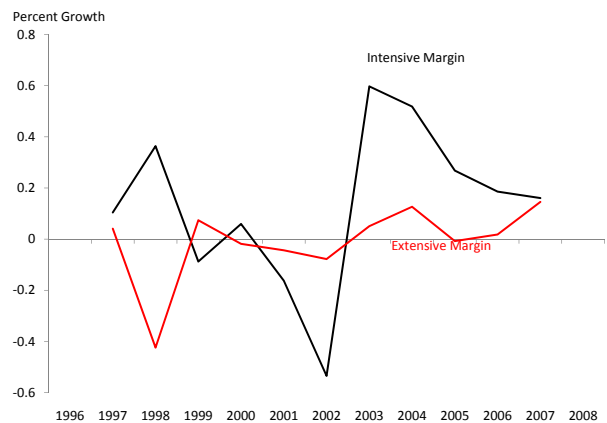
(c) HTS 10 (Quarterly)



(d) HTS 10 (Annual)



(e) HTS 10 X Country (Quarterly)



(f) HTS 10 X Country (Annual)

Figure 4: Various Extensive Margin Definitions by Quarterly and Annual Data



4(c) and 4(d) use the 10-digit HTS definition, and Figures 4(e) and 4(f) define goods as the interaction of the 10-digit HTS code and exporting country. Argentina implemented HTS revisions in 1996/1997 (though it is unclear which month), May 2002, and May 2007. This series of revisions potentially introduces an upward bias in our calculation of the extensive margin's importance. We use the concordance in Pierce and Schott (2009) to attempt to solve this problem, but can only apply this procedure for the 6-digit HTS codes. Pierce and Schott base their concordance on U.S. data, and 6-digit is the most disaggregated level at which the codes are internationally comparable. These adjustments make little qualitative or quantitative difference. As with the extensive margin of importers, the quantitative importance of the extensive margin of imported products is small.<sup>13</sup> (One exception is 1997, when the changing code definitions clearly impacted the 10-digit disaggregation.)

	Total	% Intensive	% Extensive
Firm	-69%	0.89	0.11
HTS 6	-69%	1.00	0.00
HTS 10	-69%	0.92	0.08
HTS 6 X Cty	-69%	0.91	0.09
HTS 10 X Cty	-69%	0.79	0.21

Table 2: Intensive and Extensive Margins, 2000–2002

Table 2 summarizes these results and splits total trade adjustment for 2000–2002 into intensive and extensive margins for varying product definitions. Total imports in 2002 were 69 percent below their already depressed levels in 2000 and these flows were generated by about half as many importing firms. However, the last column of the top row shows that the contribution to the 69 percent decline from the firm extensive margin was less than 11 percent, or 8 percentage points, and the last column of the second row shows that essentially none of this adjustment came from dropped 6-digit product categories. Very little trade adjustment at business-cycle frequencies, even in the event of a large contraction in imports,

<sup>13</sup>We have also looked at the trade patterns for 1996–2008 of a constant set of goods or importers chosen to include all goods of firms involved in trade in a particular year. The exit of imported products is virtually irrelevant for the long-term change in imports through the crisis — from late 1998 to early 2002 — and new products explain at most about one-quarter of import growth from 2002 to late 2006. We have separately generated these plots by good type and the pattern is very similar across 1-digit end-use categories.

is explained by firm entry and exit or by product entry and exit at the aggregate level. This finding extends the findings in Bernard, Jensen, Redding, and Schott (2009) and Arkolakis, Demidova, Klenow, and Rodriguez-Clare (2008) to characterize a dramatically larger trade adjustment.

***Finding 2: The within-firm churning of inputs, which we call the “sub-extensive margin,” plays a sizeable role in aggregate trade adjustment.***

We now consider changes in the mix of products imported by each firm, a margin we call the sub-extensive margin. In contrast to the extensive margin of importers or goods at the economy-wide level, this within-firm margin plays an essential role in aggregate trade adjustment. This result is depicted in Figure 5, where the sub-extensive margin is defined firm-by-firm and includes changes in imports for continuing importers due to newly imported or newly dropped goods (defined, as above, in a variety of ways).<sup>14</sup> The black lines plot the contribution to the total change in imports coming from continuing importer-product combinations (“the sub-intensive margin”), while the red lines plot the combined contribution from within-importer variety churning (“the sub-extensive margin”) and entry or exit of firms themselves (“the extensive margin”). Notice that, in juxtaposition to Figure 4, the declines in the red and black lines during the crisis are of a similar magnitude in Figures 5(a) to 5(d). In fact, Figures 5(a) and Figures 5(c) show that the sub-extensive and extensive margins can explain more than 50 percent of adjustment during the peak crisis quarter. This is consistent with Bernard, Jensen, Redding, and Schott (2009), who also note significant within-firm trade variety churning in U.S. data and conjecture that the welfare effect of increasing product varieties is underestimated in country-level measures.

Table 3 quantifies more precisely the importance of these margins by listing the fraction of the 69 percent overall decline in dollar imports from 2000 to 2002 as explained by the different definitions of the extensive, sub-extensive, and sub-intensive margins. Table 2 showed that whether the extensive margin is defined as entering/exiting firms or products (whether HTS-6 or HTS-10) at the country level, it explains little of the decline. By contrast, the third column of Table 3 shows that within-firm changes in import categories explains a

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<sup>14</sup>We omit separate plots of this disaggregation by end-use but have confirmed that the sub-extensive margin is significant for each of the end-use categories (with the automotive sector as the only exception).

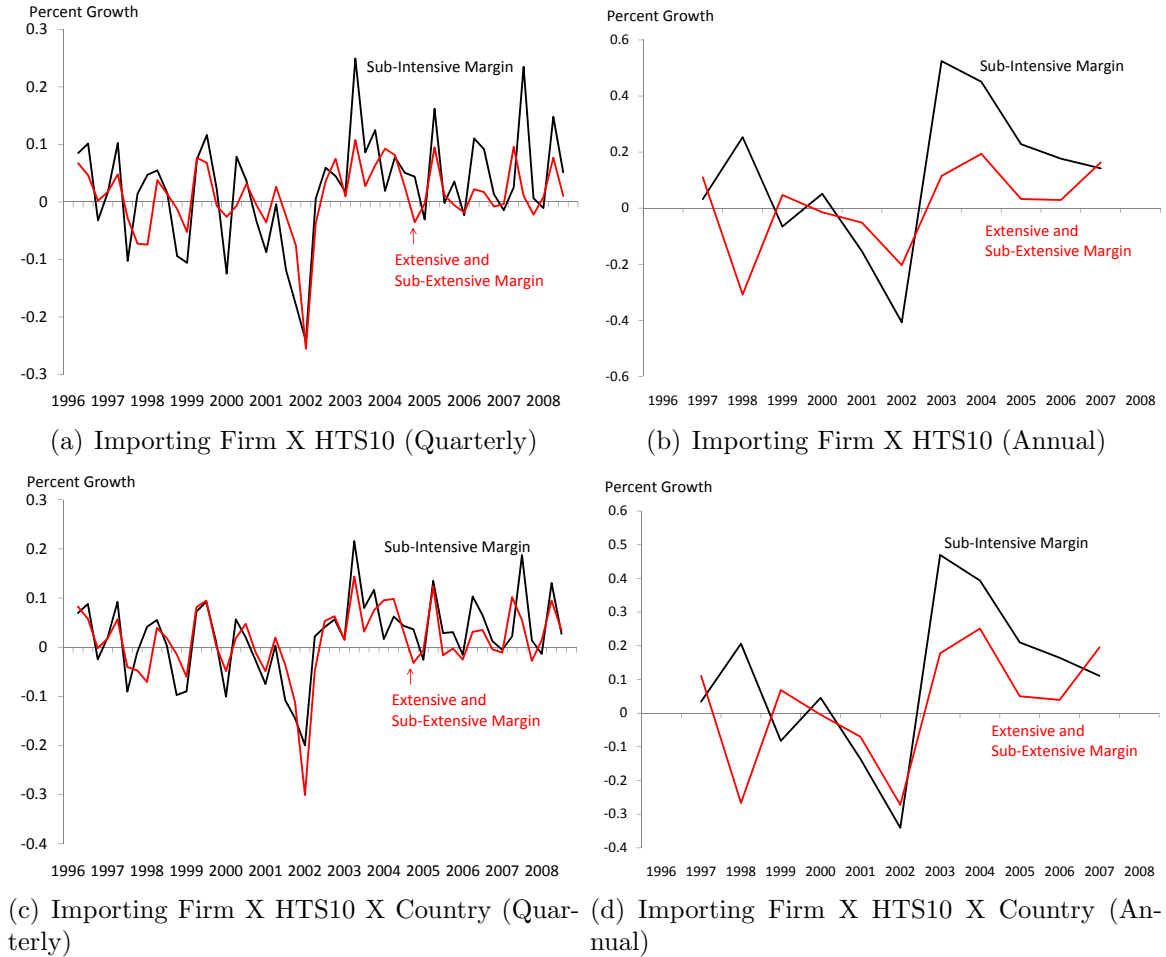


Figure 5: Sub-Extensive Margin

large share up to 45 percent of the decline, even over a two year period, depending on the product variety definition used.

The importance of the sub-extensive margin (*Finding 2*) is consistent with the small role played by the country-level extensive margin (*Finding 1*) because there is heterogeneity across firms in the products imported. For example, imagine that before the crisis two firms, Siemens Argentina and C.T.I., both imported the same semiconductor, but C.T.I. stopped importing the chip after the peso depreciation. In this case, the country-level product extensive margin would show no dropped products but there would be sub-extensive margin adjustment capturing the elimination of C.T.I.'s semiconductor imports.

Figure 6 groups HTS 10-digit products into percentiles based on their size of imports dur-

	Total	% Sub-Intensive	% Sub-Extensive	% Extensive
HTS 6	-69%	0.71	0.18	0.11
HTS 10	-69%	0.56	0.33	0.11
HTS 6 X Cty	-69%	0.54	0.35	0.11
HTS 10 X Cty	-69%	0.44	0.45	0.11

Table 3: Sub-Intensive, Sub-Extensive, and Extensive Margins, 2000-2002

ing the four quarters ending in September 2001, before the crisis.<sup>15</sup> We exclude country-level extensive margin products that were dropped from Argentina’s aggregate import bundle. The blue circles indicate the share of importer-product combinations in each of these percentiles that were dropped during the following four quarters. For any grouping of imported products, somewhere between 60 and 75 percent of the firms that imported it before the crisis stopped doing so subsequently. Many imported products which are dropped by a clear majority of importers are not considered to be dropped varieties at the aggregate level because a minority of firms continue to import them. Perfect synchronization is required across importers in terms of the products they add or drop for the product extensive margin to show up at the country level, an occurrence which would correspond to a blue circle reaching 1.0 in Figure 6.

***Finding 3: Smaller importers typically experienced a greater percentage decline in imports than larger importers. Further, the relative importance of the three adjustment margins varies with firm size.***

The pattern of trade adjustment varies with the size of the importer (as proxied by the size of imports). Figure 7(a) divides firms into percentiles based on the size of their imports in 2000.<sup>16</sup> The circles clearly increase (become less negative) as one moves from the smallest firms on the left to the larger firms on the right, indicating that the largest buckets of importers had smaller magnitude declines in their imports from 2000 to 2002.<sup>17</sup> This

<sup>15</sup>Products in the 25th/50th/75th percentiles had initial annual import volumes of about \$30,000/\$165,000/\$800,000.

<sup>16</sup>Firms in the 25th/50th/75th percentiles had initial annual import volumes of about \$50,000/\$210,000/\$770,000.

<sup>17</sup>Figures 7(a) and 7(b) as well as the regressions in this section all omit the very small share of firms

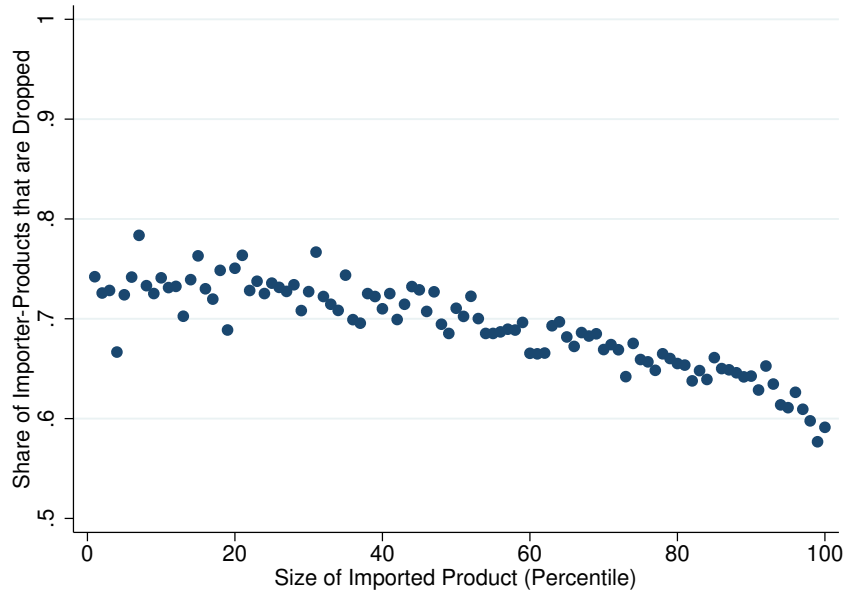
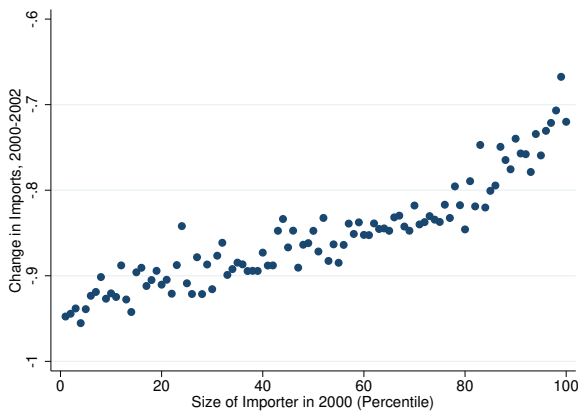
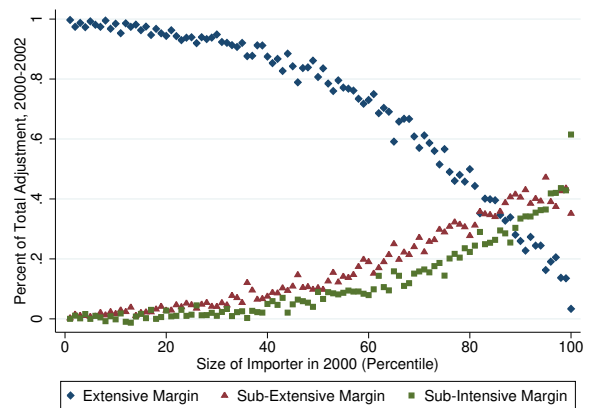


Figure 6: Different Firms Drop Different Products

pattern holds within small and large importers and is driven in part by the greater share of smaller firms that exit trade.



(a) Size and Import Decline, 2000-2002



(b) Size and Margin of Adjustment, 2000-2002

Figure 7: Adjustment by Importer Size, 2000–2002

To show this, we can decompose these trade declines into the three margins of adjustment. Firms that stop importing altogether adjust along the extensive margin. The remaining firms (nearly all in the smallest 5 percentiles to the left of the plots) that exhibited an increase in imports of more than 100 percent.

adjust using a combination of the sub-extensive margin, which is the dropping of imported varieties (or addition of new ones), and the sub-intensive margin, which is the reduction (or increase) in flows within a variety with continuing imports. Figure 7(b) plots the share of each of these three margins in the adjustment of existing combinations of importing firm and HTS 10-digit products pooled by the percentile of the firm’s total imports in 2000 (our proxy for size).<sup>18</sup> The three margins, of course, must sum to 1.

Diamond markers are used to plot extensive margin adjustment, and so a diamond placed at a y-axis value of 1 would mean that all importers within that percentile exited trade in 2000. The declining diamond marker values indicates that the prevalence of extensive margin adjustment declines as firm size increases. Differences between the sub-extensive and sub-intensive margins are less stark, but the relative importance of the sub-intensive margin is greatest among the very largest firms, as evidenced by the fact that the square markers are above the triangle markers for the very largest firms on the right. Heterogeneity in the importance of these margins underlies the heterogeneity in the degree of trade adjustment across firms of different sizes.<sup>19</sup>

The fact that the relative importance of the extensive margin and the magnitude of changes in imports declines with size across essentially all sub-regions of the importer size distribution suggests that this effect is not driven by industry composition or by the difference between multinationals and domestic firms. However, to test this more formally, we run a series of regressions of the form:

$$\widehat{v}_i = \beta_0 + \beta_1 \ln(v_{i,2000}) + \beta_2 \text{sector} + \beta_3 \text{MNC} + \varepsilon_i,$$

where  $\widehat{v}_i$  is the growth of firm  $i$ ’s imports from 2000 to 2002,  $v_{i,2000}$  is the level of firm  $i$ ’s imports in 2000, “sector” is a dummy variable that corresponds to the 10 different primary sectors identified in the Capital IQ database, and “MNC” is an indicator for when the firm is a multinational.<sup>20</sup> We can only run this regression with the approximately 1,350 firms

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<sup>18</sup>The plot ignores the small value of firm-product combinations that were added in 2002 relative to 2000.

<sup>19</sup>Some of these patterns are consistent with trade flows being innately lumpy as in Armenter and Koren (2010). In our analysis below, it makes little difference whether the patterns are generated by lumpiness or by fixed costs, so long as they generate heterogeneity in trade adjustment and cause firms to drop varieties.

<sup>20</sup>We are motivated by work such as Desai, Foley, and Hines (2004) in considering whether a firm is a

that match with the Capital IQ database in 2000. This set represents more than half of all import flows, but the small number of observations rules out inclusion of more covariates. We run this regression without dummies, with sector dummies, and with both sector dummies and a dummy for multinationals. The sector dummies pick up a moderate amount of cross-sector heterogeneity and the multinational dummy suggests that imports by multinationals dropped about 7 percentage points less than domestic firms. However, the coefficient on size,  $\beta_1$ , is positive and significant at the 1 percent level in all three regressions.<sup>21</sup>

***Finding 4: Assuming imported inputs are combined in a CES aggregator, the scale of the firm-level extensive margin adjustment implies that the price of the imported input bundle increased up to 13 percentage points more than the increase implied by aggregate data.***

As is well known, the ideal price index of a CES production function changes due to both input prices and the number of input varieties. Let  $M_t$  be a CES aggregate of varieties  $k \in \Psi_t$  with prices  $p_{k,t}$  that combine with an elasticity of substitution  $1/(1 - \theta)$ . Following Feenstra (1994), we write the growth of the unit import cost index  $\widehat{P}_{M_t}$  as:

$$\begin{aligned} \widehat{P}_{M_t} &= \frac{P_{M_t}(p_{k,t}; k \in \Psi_t)}{P_{M_{t-1}}(p_{k,t-1}; k \in \Psi_{t-1})} \\ &= \left( \frac{P_{M_t}(p_{k,t}; k \in \Psi_t \cap \Psi_{t-1})}{P_{M_{t-1}}(p_{k,t-1}; k \in \Psi_t \cap \Psi_{t-1})} \right) \left( \frac{\sum_{\Psi_t} v_{k,t} / \sum_{\Psi_{t-1} \cap \Psi_t} v_{k,t}}{\sum_{\Psi_{t-1}} v_{k,t-1} / \sum_{\Psi_{t-1} \cap \Psi_t} v_{k,t-1}} \right)^{(\theta-1)/\theta} \\ &= \widehat{P}_{\widetilde{M}_t} \mathbb{F}_t, \end{aligned} \tag{2}$$

where  $v_{k,t}$  is the spending on input  $k$  at time  $t$  and  $\widehat{P}_{\widetilde{M}_t}$  is growth in unit costs that ignores differences in  $\Psi_{t-1}$  and  $\Psi_t$ .  $\mathbb{F}_t$  captures the impact on unit costs of a change in varieties.

It also equals the factor by which growth in a conventionally measured price index  $\widehat{P}_{\widetilde{M}}$  will

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multinational since the ability to borrow through internal credit markets might plausibly have mattered during this episode. Firms with headquarters in foreign countries are classified as multinationals. When a firm's listed headquarters was in Argentina, research assistants looked in industry databases such as Hoovers as well as company websites to try determine if any foreign operations existed. If so, we label the company a multinational. If no foreign operations were found, or if the company does not have a website, we label it a domestic firm. If anything, this vetting errs on the side of having less multinationals. With this classification, multinationals account for about three quarters of all imports of firms included in the Capital IQ database.

<sup>21</sup>We do note that these regressions are more sensitive to specification than would be suggested by Figure 7(a). This is because by including only the largest firms (which match with the Capital IQ database), we significantly limit the degree of size variation in the data and omit most extensive margin adjusters.

differ from growth in the true index  $\widehat{P}_M$ .

The first column of Table 4 lists the aggregate factor  $\mathbb{F}$  calculated from aggregate data for 2000–2002 for various definitions of product variety and using an elasticity equal to 4, a value near the middle of a relatively wide range of estimates found in a large literature.<sup>22</sup> When the extensive margin is defined at the country level without taking into account the within-firm sub-extensive margin,  $\mathbb{F}$  ranges from 0.992 to 1.012 percent depending on the granularity with which we define product categories. None of these corrections is meaningfully different from 1. Consistent with our finding that very little trade adjustment is done via the country-level extensive margin (*Finding 1*), the aggregate data suggest there is no meaningful impact from dropped varieties on the cost of an imported input bundle.<sup>23</sup>

$\theta = 0.75$ Percentiles Included:	$\mathbb{F}$	Weighted Average of $\mathbb{F}_i$		
	all	all	(5,95)	(20,80)
HTS 6	1.000	1.087	1.046	1.034
HTS 10	0.992	1.110	1.068	1.060
HTS 6 X Country	1.012	1.163	1.099	1.063
HTS 10 X Country	1.004	1.176	1.096	1.097
Simple Average	1.002	1.134	1.077	1.064

Table 4: Impact of Product Extensive Margin on Imported Input Costs, 2000-2002

Next, we use the information available in the firm-level data to calculate the impact of the product sub-extensive margin on the cost to each firm of its imported input bundle. The calculation is identical to that in Equation (2) but adding a firm index  $i$  to all values and yielding:  $\widehat{P}_{M_{i,t}} = \widehat{P}_{\widetilde{M}_{i,t}} \mathbb{F}_{i,t}$ . The second through fourth columns of Table 4 give the trade-weighted average of firm-level factors  $\mathbb{F}_i$  including all firms, after excluding the top and bottom 5 percent of correction factors, and after excluding the top and bottom 20 percent of correction factors. We only include firms that had positive import flows in both

<sup>22</sup>For example, Broda and Weinstein (2006) define a product variety as the interaction of an HTS 10-digit code and country and obtain a median elasticity estimate of 2.9 and a mean elasticity estimate of 8.2. Eaton and Kortum (2002) generate an estimate of 8.28, Bernard, Eaton, Kortum, and Jensen (2003) give an estimate of 3.6, and the estimate in Eaton, Kortum, and Kramarz (2011) equals 4.87.

<sup>23</sup>This is similar to the finding in Arkolakis, Demidova, Klenow, and Rodriguez-Clare (2008) who evaluate the effect of trade liberalization in Costa Rica on increased import variety over the period 1986–1992. They find that the gains from importing a larger variety of goods following the liberalization is small because import spending is concentrated in a few products that were imported before liberalization. They estimate the  $\mathbb{F}$  to be 0.997 for consumer goods and 1 for intermediate goods.



2000 and 2002. The impact of the product sub-extensive margin  $\mathbb{F}_i$  differs somewhat across specifications, product definitions, and treatment of the outliers, but is always economically significant. The average value in these columns ranges from 6.4 to 13.4 percent. Consistent with *Finding 2*, under the assumption of a CES production function, sub-extensive margin adjustment driven by within-firm input churning has a large impact on the cost of an imported input bundle. In essence, rather than focusing only on the traditional terms of trade measured at the country level, we show that one must focus on the firm-level terms of trade.

It is clearly the case that as the level of disaggregation increases more of the adjustment will be classified as extensive or sub-extensive, so a reasonable question is what is a meaningful level of disaggregation for this exercise? Previous quantification of the product extensive margin, as in Broda and Weinstein (2006), Broda, Greenfield, and Weinstein (2006), or Arkolakis, Demidova, Klenow, and Rodriguez-Clare (2008) has been done at the country or sector level. This categorization is appropriate under the assumption that all imports are final goods consumed by agents with homothetic preferences or are intermediates consumed by a representative firm. In such a setup, if a good enters the country, it also enters the representative consumer's consumption bundle or the representative firm's input bundle. By contrast, our calculations assume that all imported goods are intermediates used only by the importing firm. In the context of the above example, we assume Siemens' continued semiconductor imports reflects their continued use of the input in production, while C.T.I.'s dropping of that particular input implies it is no longer using it in production.

In essence, we assume that when a firm does not import a variety it is not using that variety in production. We believe this is generally the most appropriate assumption, but it is violated if firms purchase inputs from a domestic distributor who imports it or if firms draw down holdings of a particular input from inventory.<sup>24</sup> As discussed above, the share of imports due to distributors is low throughout the sample and in fact decreases during the crisis, ruling out the first concern.

To get a quantitative sense for the importance of the inventory mechanism for our measurements, we would ideally like to condition firm import behavior on changes in their

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<sup>24</sup>Alessandria, Kaboski, and Midrigan (2010) emphasize the importance of the inventory channel in trade adjustment.

inventories. Unfortunately, firm or detailed sector level data on inventories are not broadly available for Argentina. As an alternative, we classify 6-digit HTS sectors into three groups with low, medium, and high inventory intensities, based on the inventory/sales ratio in the corresponding 3-digit NAICS manufacturing sector in U.S. Census data from 2000. Figure 8 plots the evolution of the value of imports for the three groups, where the lines are each normalized to equal one prior to the crisis. The plot shows differential trajectories through the crisis period, despite similar import behavior in the runup to the crisis.<sup>25</sup> For instance, comparing 2002:Q1-Q2 with 2001:Q1-Q2, low inventory intensity imports dropped by 53 percent, compared to a 73 percent decline in the other two categories.

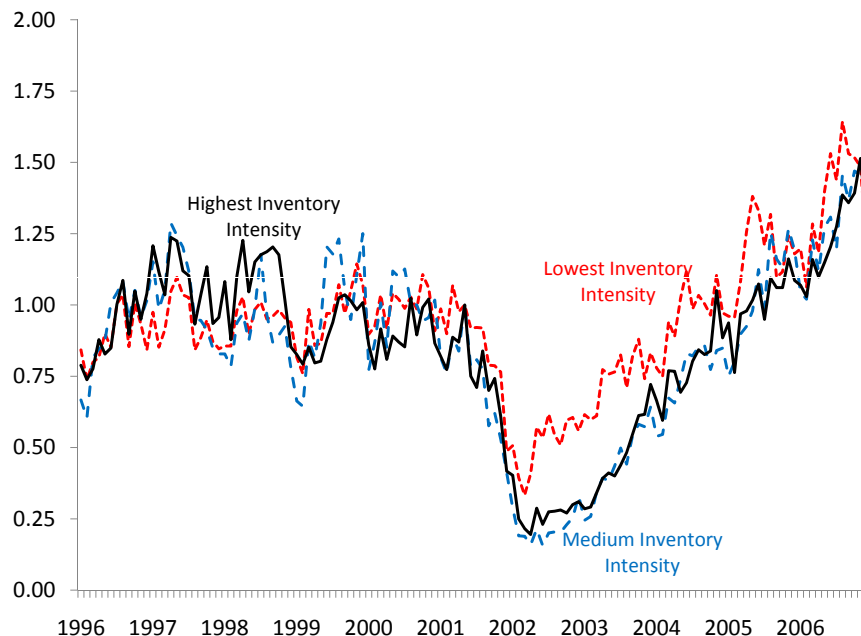


Figure 8: Inventory Intensity and Import Decline

These results show that ignoring inventories may lead to an overstatement of the change in varieties used in production because the import decline was steepest in sectors presumably holding large inventories. For this reason, we focus on the 2000–2002 period. Given that U.S. manufacturing inventories typically equal from 1 to 2 months of sales, this substantially longer period should alleviate the concern that firms continued producing with inventoried imported inputs. In our simulations in Section 5.7, we will also take inventories into account

<sup>25</sup>The average monthly inventory to sales ratio in the three groups equals 1.2, 1.5, and 1.9.

by reducing the magnitude of the simulated shock such that the drop in imported input use is consistent with the more muted decline seen in imports of the lowest inventory intensive categories.

Finally, one might be concerned that the reduction of import varieties need not impact production costs if there is a similar reduction in final good varieties. For instance, if each import variety is used by multiproduct firms to produce a single output variety, then the reduction in imports can simply follow from a reduction in final good varieties without altering in any way the production of continuing goods (though this reduction will still have welfare effects). The best evidence against such a hypothesis would be data on total varieties produced, which we do not have. However, we can proxy for the number of varieties available for domestic consumption by looking at the varieties exported from Argentina over this period. Figure 9(a) shows that in the aggregate there is a small secular increase in both import and export varieties from 2000 to 2008. Imported varieties, however, sharply collapsed during the crisis while export varieties barely changed (and, if anything, increased).<sup>26</sup>

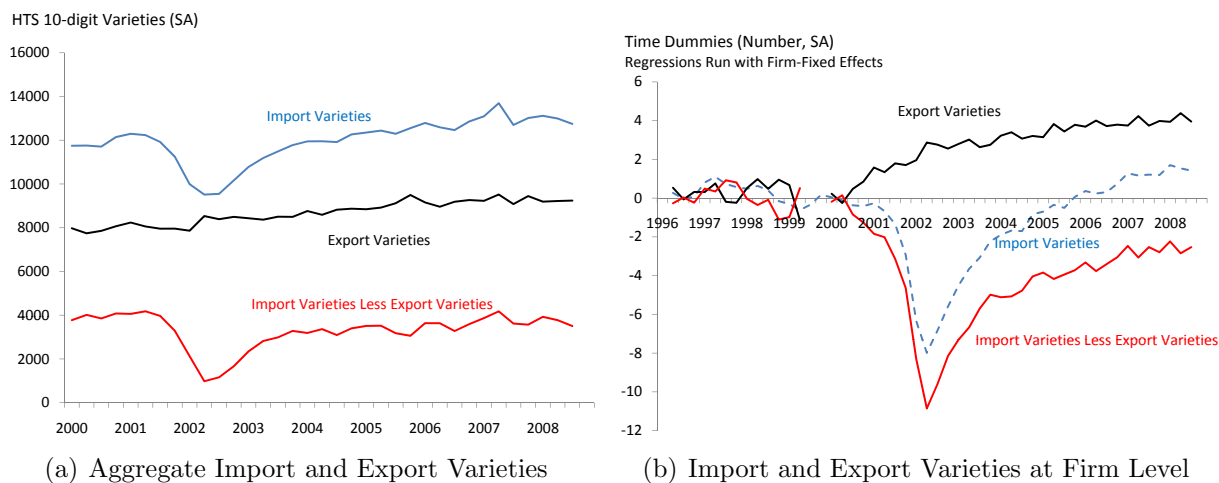


Figure 9: Export Varieties did not Decline Along with Import Varieties

Even stronger evidence comes from matching the imports and exports of the same firm and regressing import varieties, export varieties, and their difference, on time fixed effects after absorbing firm fixed effects. The quarter fixed effects from this regression are plotted in Figure 9(b) and show that while the number of both import and export varieties have

<sup>26</sup>Plots 9(a) and 9(b) have been seasonally adjusted by removing estimated quarter time-effects.

a similar long-term growth rate from 1996 to 2008, they diverge dramatically during the crisis, with firms importing far fewer varieties to support relatively stable numbers of export varieties.<sup>27</sup> This evidence suggests that it was not the case that all (or any) of the decline in imported input varieties was accompanied by a reduction in final good varieties.<sup>28</sup>

In sum, the micro data indicate that dropped product varieties by continuing importers, the sub-extensive margin, plays an important role in trade adjustment, a conclusion that could not be inferred from aggregate data. In this sense, studying the micro data is important for thinking about the appropriate model for trade in intermediate inputs. This in turn is important for understanding the impact on productivity of trade shocks, something we turn to in the next sections.

## 4 Multi-Input Firms, Trade, and Productivity

Consistent with *Findings 1-4*, we build a model where firms combine labor, capital, and a continuum of imported and domestically sourced intermediate inputs to produce a unique variety of good that is used both for final consumption and as an intermediate input by other firms. The intermediate input aggregator in the production function displays a “love of variety” feature with inputs being imperfectly substitutable as in Ethier (1982). Firms differ in their technologies and they pay a fixed cost for each variety of input that is imported.<sup>29</sup>

This model generates both within-firm adjustment on the sub-extensive margin and heterogeneity in trade adjustment across firms. Firms with worse technology will not have sufficient scale to cover the fixed costs of importing a larger number of varieties. Consequently, firms will differ in the share of their spending on inputs that are imported. This

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<sup>27</sup>As discussed in the data description, our economy-wide export data have large gaps before 2000, which is why Figure 9(a) starts in 2000. Our firm-level export data are of lower quality before 2002:Q1, but if the missing flows reflect the omission of representative exporters in their entirety, rather than the omission of some subsets of given exporters’ shipments, then the fixed effect regression in Figure 9(b) will be unaffected. At a minimum, the export series from 2002 onward and the entire import series in Figure 9(b) are uncorrupted by data concerns. Even over this smaller region, the evidence suggests export varieties did not drop along with import varieties.

<sup>28</sup>Since we do not have data on purchases of domestic input varieties, we cannot evaluate the impact on the domestic input component of unit costs of changes (if any) of the number of domestic varieties used.

<sup>29</sup>Motivated by *Finding 1*, there is no fixed cost for entry into import status and therefore firm entry and exit will play no role in trade adjustment. We have performed calculations with a fixed entry cost calibrated to match the data and found little difference with a model without fixed entry costs in its implications for productivity.

endogenously generates an additional source of variation in the unit cost of production across firms, in addition to the exogenous technological differences. We use the model to evaluate the channels through which an imported input cost shock can affect the welfare relevant measure of manufacturing productivity. We show that these effects are sizable and when calibrated to Argentina can generate a productivity decline of over 5 percentage points.

The aggregate data misleadingly imply that dropped input varieties were not an important part of adjustment and give no evidence of non-homotheticities in import demand. In the absence of firm-level data, therefore, the most natural model of trade during the Argentine crisis would omit fixed costs. We compare our benchmark model to this model and show that the model with sub-extensive margin adjustment exhibits a productivity decline that is 30 percent, or 1.2 percentage point, larger. Due to mismeasurement associated with dropped varieties, the implications are even greater for measured productivity.

## 4.1 Environment

Each domestic manufacturing firm  $i$  produces a unique variety of good using the production function:

$$Y_i = A_i(K_i^\alpha L_{p,i}^{1-\alpha})^{1-\mu} X_i^\mu, \quad (3)$$

where  $X_i$  is the intermediate input bundle,  $K_i$  is capital,  $L_{p,i}$  is the labor input used in production, and  $A_i$  is the firm's exogenous technology.  $X_i$  combines a bundle of diverse intermediate inputs produced domestically,  $Z_i$ , and another bundle of imported intermediate inputs,  $M_i$ , according to the CES aggregator:

$$X_i = [Z_i^\rho + M_i^\rho]^{\frac{1}{\rho}},$$

where the input bundles are themselves CES aggregates:

$$Z_i = \left[ \int_j z_{ij}^\theta dj \right]^{\frac{1}{\theta}} \quad M_i = \left[ \int_{k \in \Omega_i} m_{ik}^\theta dk \right]^{\frac{1}{\theta}}.$$

$z_{ij}$  represents firm  $i$ 's use of domestically produced inputs  $j$ ,  $\Omega_i$  is the set of foreign input varieties imported by  $i$ , and  $m_{ik}$  is the quantity of imported input  $k$ . The elasticity of

substitution  $1/(1-\theta)$  is the same within domestic varieties and within foreign varieties, while  $1/(1-\rho)$  is the elasticity of substitution between the bundles of imported and domestically produced inputs.

The output of each domestic firm  $i$  is used to produce a final good  $g_i$  and as an intermediate input  $z_i$  that is used domestically by other firms. This captures the roundabout nature of production. There are no exports:

$$Y_i = g_i + z_i = g_i + \int_j z_{ji} dj.$$

The aggregate final good  $G$  is formed by aggregating all the individual final goods  $g_i$ :

$$G = \left[ \int_i g_i^\theta di \right]^{\frac{1}{\theta}},$$

where  $0 < \theta < 1$  and  $1/(1-\theta)$  is the elasticity of substitution across the different varieties used in producing the final good.<sup>30</sup>

There is a fixed cost  $f$  denominated in units of labor that is an increasing function of the measure of varieties imported. The presence of these fixed costs is consistent with the empirical evidence we presented earlier and the evidence in Bernard, Jensen, and Schott (2009) and Halpern, Koren, and Szeidl (2009). Total fixed costs can be written as:

$$F(|\Omega_i|) = f |\Omega_i|^\lambda,$$

where  $f > 0$ ,  $\lambda > 0$ . We denote the labor used to pay fixed costs for firm  $i$  as  $L_{f,i}$ . This specification implies that all firms will import at least some positive quantities. Consistent with *Finding 1*, firm entry into and exit from import status will not be important for aggregate trade adjustment.

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<sup>30</sup>For simplicity we assume that the elasticity of substitution across domestic varieties in producing good  $j$  is the same as across domestic varieties in producing the final good. This will imply that the elasticity of demand faced by firm  $i$  is a constant equal to  $1/(1-\theta)$ . If the elasticities differ then the elasticity of demand faced by firm  $i$  is a weighted average of the elasticity of the final good demand and of the intermediate input demand, where the weights reflect the relative shares of output going to the final demand sector compared to intermediate input demand.

## 4.2 Firm's Problem

Firms engage in monopolistic competition. Each firm  $i$  chooses  $K_i$ ,  $L_{p,i}$ , and the vector  $\{z_{ij}\}$ , given the price of labor  $w$ , the rental price of capital  $r$ , and the set of domestic intermediate input prices  $\{p_j\}$ . They also choose the set of imported varieties  $\Omega_i$  and the amount of each variety  $k$ ,  $m_{ik}$ .

We assume that the price of all imported goods is  $p_m$ , and since all imported varieties are identical, the quantity of each imported foreign variety will be the same,  $m_i$ .<sup>31</sup> The firm's unit cost function is then:

$$C_i = \frac{1}{\mu^\mu(1-\mu)^{1-\mu}} \frac{P_V^{1-\mu} P_{X_i}^\mu}{A_i}, \quad (4)$$

where  $P_V = \alpha^{-\alpha}(1-\alpha)^{-(1-\alpha)} r^\alpha w^{1-\alpha}$  is a constant that does not vary across firms, and:

$$P_{X_i} = \left( P_Z^{\frac{\rho}{\rho-1}} + P_{M_i}^{\frac{\rho}{\rho-1}} \right)^{\frac{\rho-1}{\rho}}.$$

The domestic input price index:  $P_Z = \left[ \int_i p_i^{\frac{\theta}{\theta-1}} di \right]^{\frac{\theta-1}{\theta}}$  is the same for all firms, while the imported input price index:

$$P_{M_i} = \left[ \int_{k \in \Omega_i} p_m^{\frac{\theta}{\theta-1}} \right]^{\frac{\theta-1}{\theta}} = p_m |\Omega_i|^{\frac{\theta-1}{\theta}},$$

differs across firms to the extent that they import a different measure of varieties  $|\Omega_i|$ . The larger the measure of imported varieties used the lower the intermediate input cost index, all else equal. The number of imported input varieties used by each firm can vary, while the number of domestic input varieties remains fixed. We make this assumption because fixed costs (if any) required for buying domestic varieties are likely much smaller than those for importing goods and because we lack data on domestic varieties used for production.

Firm  $i$ 's demand for production workers  $L_{p,i}$ , capital  $K_i$ , domestically sourced inputs

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<sup>31</sup>We make this simplifying assumption because the main comparative static we consider is the effect of the Argentine peso devaluation on import purchases. This large common shock likely dominated any idiosyncratic movement in import prices.

$\{z_{ij}\}$ , and imported inputs  $\{m_i\}$  are given by the first-order conditions:

$$\begin{aligned}
wL_{p,i} &= (1 - \mu)(1 - \alpha)C_iY_i, \\
rK_i &= (1 - \mu)\alpha C_iY_i, \\
P_{X_i}X_i &= \mu C_iY_i, \\
z_{ij} &= \left(\frac{p_j}{P_Z}\right)^{\frac{1}{\theta-1}} \left(\frac{P_Z}{P_{X_i}}\right)^{\frac{1}{\rho-1}} X_i \text{ for each } j, \text{ and} \\
m_i &= \left(\frac{p_m}{P_{M_i}}\right)^{\frac{1}{\theta-1}} \left(\frac{P_{M_i}}{P_{X_i}}\right)^{\frac{1}{\rho-1}} X_i.
\end{aligned} \tag{5}$$

The demand faced by domestic firm  $i$  for its output is the sum of final demand  $g_i$  and intermediate demand  $z_i$ :

$$g_i + \int_j z_{ji}dj = \left(\frac{p_i}{P_G}\right)^{\frac{1}{\theta-1}} G + \int_j \left(\frac{p_i}{P_Z}\right)^{\frac{1}{\theta-1}} \left(\frac{P_Z}{P_{X_j}}\right)^{\frac{1}{\rho-1}} X_jdj,$$

where  $P_G$  is the CES price index for final varieties  $g_i$ . The price set by firm  $i$  is  $p_i = C_i/\theta$ . Firm  $i$  then chooses  $\Omega_i$  to maximize profits net of the cost of importing varieties:

$$\Omega_i = \arg \max_{\Omega_i} \{\Pi_i - wF(|\Omega_i|)\},$$

where  $\Pi_i$  are profits gross of all fixed costs.

It follows that firms with better technology will import a larger measure of varieties as long as the second-order conditions for an interior solution for  $\Omega_i$  are satisfied.<sup>32</sup> Since varieties are homogenous the identity of each specific imported variety is indeterminate. The model is then consistent with firms dropping disjoint sets of varieties that are generally not dropped in the aggregate, as was the case in the empirical evidence.

Define  $\gamma_i \equiv \frac{P_Z Z_i}{P_{X_i} X_i}$  to be the share of domestic inputs in total spending on intermediates.  $\gamma_i$  is decreasing in  $A_i$ . The domestic input price index can be expressed as:

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<sup>32</sup>The second order condition requires  $\frac{\rho(1-\theta)}{\theta(1-\rho)} - \lambda + \left(\frac{\rho}{1-\rho} - \frac{\mu\theta}{1-\theta}\right) \frac{(\theta-1)}{\theta} (P_{M_i}/P_{X_i})^{\frac{\rho}{\rho-1}} < 0$ . This is satisfied as long as  $\lambda$  is sufficiently high.  $(P_{M_i}/P_{X_i})^{\frac{\rho}{\rho-1}}$  equals the share of intermediate input spending on imported inputs and therefore belongs to the interval  $(0, 1)$ .



$$P_Z = \frac{(r^\alpha w^{1-\alpha})}{(\epsilon\theta)^{\frac{1}{1-\mu}}} Q_{\gamma\theta\rho}^{-\frac{1}{1-\mu}},$$

where

$$Q_{\gamma\theta\rho} = \left[ \sum_i \gamma_i^\mu \left(\frac{\rho-1}{\rho}\right)^{\frac{\theta}{1-\theta}} A_i^{\frac{\theta}{1-\theta}} \right]^{\frac{1-\theta}{\theta}},$$

and  $\epsilon = \mu^\mu (1-\mu)^{1-\mu} (\alpha^\alpha (1-\alpha)^{1-\alpha})^{1-\mu}$ .

The price index therefore depends on the joint distribution of firm-level technologies  $A_i$  and import shares  $(1-\gamma_i)$ , which captures the heterogeneity in unit costs of production arising from exogenous differences in  $A_i$  and endogenous differences in  $\gamma_i$ . Since high  $A_i$  firms have lower  $\gamma_i$  they have lower unit costs of production. This cost advantage is decreasing in the elasticity of substitution across domestic and foreign inputs,  $\rho$ . The revenue, profits, and value added will be more dispersed in this environment than in one without fixed costs.

## 5 Productivity

The goal of this section is to evaluate the impact of a foreign input cost shock on the productivity of the manufacturing sector and the resulting implications for the welfare of a representative agent in the economy. We measure firm level productivity  $\mathbf{PR}_i$  using the Solow residual:

$$\Delta \ln \mathbf{PR}_i = \Delta \ln Y_i^{VA} - s_{L_i} \Delta \ln L_i - s_{K_i} \Delta \ln K_i, \quad (6)$$

where  $\Delta \ln L_i$ ,  $\Delta \ln K_i$ , and  $\Delta \ln Y_i^{VA}$  denote the growth rates of labor, capital input, and value-added of the firm, and  $s_{L_i}$  and  $s_{K_i}$  denote shares of labor and capital in value added. Industry level value added is just a weighted sum of firm level value added:<sup>33</sup>

$$\Delta \ln \mathbf{PR} = \Delta \ln Y^{VA} - s_L \Delta \ln L - s_K \Delta \ln K, \quad (7)$$

where  $\Delta \ln Y^{VA} = \omega_i \sum_i \Delta \ln Y_i^{VA}$ ,  $s_L \Delta \ln L = \sum_i \omega_i s_{L_i} \Delta \ln L_i$ ,  $s_K \Delta \ln K = \sum_i \omega_i s_{K_i} \Delta \ln K_i$ , and  $\omega_i \equiv (P_i^{VA} Y_i^{VA}) / (P^{VA} Y^{VA})$  denotes firm  $i$ 's share of industry value added. Note that

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<sup>33</sup>Industry-level factor shares multiplied by growth in industry-level inputs can be written as the value-added share weighted sum of the corresponding firm-level object because all firms pay the same factor prices.

this measure of the Solow residual, often referred to as the “modified” Solow residual, has factor shares that need not sum to one. As highlighted by Basu and Fernald (2002) and Basu, Pascali, Schiantarelli, and Serven (2011), this is the welfare relevant measure of productivity.

## 5.1 Firm-level and Sector-level Productivity

The standard definition of value-added growth is:

$$\Delta \ln Y_i^{VA} \equiv \frac{\Delta \ln Y_i - s_{X_i}^Y \Delta \ln X_i}{1 - s_{X_i}^Y},$$

where  $s_{X_i}^Y = (P_{X_i} X_i) / (p_i Y_i)$  is the share of intermediate input spending in total revenues (as opposed to in value added). Equations (4) and (5), together with the optimality of constant markups, imply that  $s_{X_i}^Y = \mu\theta$  for all firms. In the appendix, we follow steps similar to those in Basu and Fernald (2002) with the distinction that we have labor that is used for fixed costs as well as for production and show that one can use a first-order approximation to express changes in the productivity of firm  $i$  as:

$$\begin{aligned} \Delta \ln \mathbf{PR}_i &= \frac{(1 - \theta)}{\theta(1 - \mu)} \left[ \Delta \ln V_i + \frac{\mu\theta}{1 - \mu\theta} (\Delta \ln X_i - \Delta \ln Y_i) \right] \\ &\quad - \frac{(1 - \mu\theta)}{\theta(1 - \mu)} s_{L_i} (1 - \omega_{L_p,i}) \Delta \ln L_{f,i} + \Delta \ln A_i / (1 - \mu). \end{aligned} \quad (8)$$

We write  $\Delta \ln V_i \equiv s_{K_i} \Delta \ln K_i + s_{L_i} \Delta \ln L_i$  for the percent change in use of primary inputs and use  $\omega_{L_p,i} \equiv L_{p,i} / L_i$  to denote the share of firm  $i$ 's labor that is used in production.

Equation (8) allows us to describe how a generic shock will impact firm-level productivity. First, productivity will change with the scale of production  $\Delta \ln V_i$  since firms have pricing power and  $\theta < 1$ . This follows because value added growth exceeds the sum of shares of payments going to primary factors times input growth in the presence of mark-ups. Why is this decline in productivity relevant from a welfare perspective? When consumers are price takers, the payments to primary inputs corresponds to the welfare loss to consumers of providing more labor (foregoing leisure) and more capital (foregoing current consumption) and the value added growth captures the welfare gain in consumption in exchange. In the presence of mark-ups, the marginal rate of transformation exceeds the marginal rate of

substitution. A decline in scale is therefore associated with a welfare loss in consumption that exceeds the welfare gain from a reduction in labor and capital. The fact that in the presence of mark-ups productivity is impacted by scale effects even when technology is unchanged goes back to Hall (1988, 1990). This argument is developed more generally and linked to welfare in Basu and Fernald (2002) and Basu, Pascali, Schiantarelli, and Serven (2011).

Second, changes in the intensity of intermediate input use,  $\Delta \ln X_i - \Delta \ln Y_i$ , will have an impact on productivity when firms have pricing power for the same reasons as changes in the scale of production do. With positive markups, the opportunity cost of using up inputs is exceeded by the gains from their contribution to value added. Importantly, in the presence of intermediate inputs,  $\mu > 0$ , even small deviations from  $\theta = 1$  can have significant effects on productivity. Below, we relate changes in this term to changes in the share of intermediate input spending on domestic inputs,  $\gamma_i$ .

A third effect on firm productivity arises from changes in the use of labor for fixed costs  $\Delta \ln L_{f,i}$ . Equation (3) shows that fixed labor has no direct effect on output. Therefore, all else equal, a decline in its use has a positive impact on this welfare-relevant measure of productivity.

Finally, the fourth term refers to changes in the technology  $A_i$  of each firm. We hold technology fixed by assumption and therefore shut down this last mechanism for productivity changes.

It is clear from equation (8) that shocks to imported input costs will have a first order impact on firm productivity in our economy. This result differs from Kohli (2004) and Kehoe and Ruhl (2008) who assume perfect competition and conclude that terms of trade shocks have no first-order effect on productivity. The difference is that we consider the case when firms have pricing power. In the limiting case of no pricing power when  $\theta \rightarrow 1$  we also obtain the result that there are no first order effects on productivity. This is seen in equation (8) as the first term collapses to zero if  $\theta = 1$  and the second term will equal zero if there are no fixed costs.

In the presence of fixed costs there will be heterogeneous adjustments in each of the non-technology terms of equation (8). Because of differential adjustments on the sub-extensive margin across firms of different sizes, the change in  $P_{M_i}$  will vary across firms. This will

imply variation in changes in the unit cost of production and consequently on the scale of production. In parallel, heterogeneity in sub-extensive margin adjustment will bring heterogeneous adjustment in fixed costs.

Next, we consider the impact on sectoral productivity of a common change in the cost of imported inputs in our model, designed to capture the effect of a large nominal exchange rate devaluation that increases the relative price of imported to domestically sourced inputs. We adopt a partial equilibrium framework that holds factor prices ( $w, r$ ) fixed and write the impact on sector-level productivity of an increase in the relative price of imported inputs as:<sup>34</sup>

$$\Delta \ln \mathbf{PR} = \frac{\mu}{1-\mu} \frac{1-\theta}{\theta\mu} \Delta \ln V \quad (9)$$

$$+ \frac{\mu}{1-\mu} \left[ \left( \frac{1-\theta}{1-\mu\theta} - \frac{1-\gamma}{1-\mu} \right) \frac{\theta-1}{\theta} \sum_i \omega_i \Delta \ln \omega_i \right] \quad (10)$$

$$+ \frac{\mu}{1-\mu} \left[ \frac{1-\rho}{\rho} \left( \frac{\theta(1-\mu)}{1-\mu\theta} + \frac{\mu(1-\gamma)}{1-\mu} \right) \sum_i \omega_i \Delta \ln \gamma_i \right] \quad (11)$$

$$- \frac{\mu}{1-\mu} (1-\gamma) \Delta \ln p_m. \quad (12)$$

The first term on the right hand side of line (9) captures the overall scale effect on productivity of the change in factor input use  $\Delta \ln V \equiv \sum_i \omega_i \Delta \ln V_i$ . The increase in foreign input costs in our economy generates an increase in the unit cost of production for firms that in turn raises the price of each firm's output relative to sectors that do not use imported inputs. This reduces the demand for the industry and consequently generates a decline in the usage of  $K$  and  $L$ .<sup>35</sup> Firm sub-extensive margin adjustment also generates movement in  $L$  by changing the use of labor associated with fixed costs.

<sup>34</sup>As discussed in the appendix, these expressions rely on the approximation  $\Delta \ln(1-\gamma_i) = -\frac{\gamma_i}{1-\gamma_i} \Delta \ln \gamma_i$ , which is valid for small shocks. In the simulation section we do not use this approximation because we study large shocks.

<sup>35</sup>Note that overall final good demand for domestic firms necessarily declines. However, firms that relied less on imported inputs are less impacted by the shock causing their share and output to increase. As firms shift from foreign to domestic inputs the relative share of spending on domestic intermediate inputs increases. The net level effect on intermediate input demand depends on both the derived demand effect for intermediate inputs following the decline in overall final demand (negative) and the increase in the relative demand for domestic versus imported inputs (positive). In Section 5.3 we obtain a net decline in total manufacturing demand/output consistent with that documented in the data when parameters are calibrated to match key moments in the data.

The next set of terms arise from heterogeneity in trade adjustment due to the interaction of fixed costs and heterogeneous technologies. The term in line (10) can in principle be positive or negative and reflects the impact of non-homothetic import demand. Because firms adjust differentially, the price of their output will adjust differentially and market shares will change endogenously (i.e.  $\Delta \ln \omega_i \neq 0$ ). As discussed above, trade (or changes in trade) induces a shift in market shares relative to the exogenous technology distribution. Lines (11) and (12) capture the impact of adjustments in import shares across the entire distribution of firms.

It is useful to compare productivity and welfare in our benchmark model to the case where there are no fixed costs in importing varieties. With no fixed costs, each firm imports the same foreign varieties and spends the same cost share on imports. Trade has the same impact on all firms' unit cost of production and consequently the full distribution of market shares  $\omega_i$  remains unchanged in response to import cost shocks. Firms with different technologies might operate at different scales but this heterogeneity is irrelevant for all aggregate measures. For example,  $\Delta \ln V_i$  is the same across firms. In this case, line (10) is equal to 0. Combining lines (11) with (12), we arrive at a term

$$-\frac{\mu}{1-\mu} \frac{1-\rho}{\rho} \frac{1-\theta}{1-\mu\theta} \Delta \ln \gamma,$$

where  $\gamma \equiv \sum_i \omega_i \gamma_i$  is the industry average of intermediate input spending on domestic inputs.

This expression resembles the finding in Arkolakis, Costinot, and Rodriguez-Clare (2011), where primary factors are in fixed supply and therefore  $\Delta \ln V = 0$ . The impact of a change  $p_m$  is an increasing function of the share of intermediates in production  $\mu$ , a decreasing function of the elasticity of substitution between domestic and foreign intermediates  $\rho$ , and is summarized by this scaled movement in  $\Delta \ln \gamma$ . In models where  $L$  and  $K$  are exogenously fixed and where there is no change in the market share of continuing importers, the impact on productivity and welfare is a simple linear function of the percent change in spending on domestic intermediate inputs.

In the case with fixed costs and heterogenous firms, the terms in lines (10), (11), and (12) do not simplify and the impact on productivity depends on the full distribution of individual

firm responses. This is because, consistent with *Finding 3*, firms respond to the same shock with a different share of their adjustment due to the sub-intensive and sub-extensive margins. Firms with more product sub-extensive margin adjustment see import volume decline more than firms with more sub-intensive margin adjustment. Line (10) reflects the differential changes in firm shares of value added and line (11) does not simplify because it is no longer the case that the change in the aggregate import share equals the import-weighted sum of changes in firm-level import shares. Also note that the sign of expression (11) is always positive. This in part reflects the positive impact on productivity from the savings of fixed cost labor implied by the shift from foreign to domestic inputs.

## 5.2 Measured Productivity

In the previous sections we focused on the impact of an import collapse on the welfare relevant measure of productivity under the assumption that the measurement of prices and quantities properly accounted for changes in input varieties. As pointed out by Feenstra (1994), however, statistical agencies in all countries employ matched-model price indices which do not adjust for changing import varieties. Therefore, if trade collapsed in part due to the product sub-extensive margin, and if production involves CES aggregation as in our model, these agencies would underestimate the true rise in import prices. If a matched model price index were used to calculate  $X_i$  from the observed spending on inputs  $(P_{X_i}X_i)$ , it would result in an overestimate of intermediate input use which would lead to a further decline in measured productivity.

Under these assumptions, we write the measured change in productivity as:

$$\Delta \ln \widetilde{\mathbf{PR}} = \Delta \ln \mathbf{PR} - \frac{\mu}{1-\mu} \frac{1-\theta}{1-\mu\theta} \sum_i \omega_i \Delta \ln(P_{X_i}/\widetilde{P}_{X_i}),$$

where  $\widetilde{P}_{X_i}$  is the mismeasured price index that does not account for the change in the varieties of imported inputs. This measurement implies a positive movement in  $(P_{X_i}/\widetilde{P}_{X_i})$  and a greater decline in measured than in actual productivity. In this sense, our firm-level data reveal that dropped import varieties are not only important for understanding the actual change in productivity but are additionally important for the practical measurement

of it.

The above analytical expressions suggest that important differences in productivity emerge in response to the same shocks depending on the underlying structure of the model. Our firm-level data and *Findings 1-4* motivated the structure of our benchmark model presented in Section 4. In the absence of simulations of the benchmark and any alternative model, however, it is hard to determine when productivity will be higher or lower in response to any given shock or if these differences are significant. We therefore turn now to simulations to compare the outcomes for productivity in models with and without fixed costs.

### 5.3 Simulation

We numerically simulate the model with a simple algorithm in which we specify the number of domestic firms, the distribution of their technologies  $G(A_i)$ , the fixed cost function  $F(|\Omega_i|)$ , an initial value for the import price  $p_m$ , and the set of parameters  $\{\theta, \rho, \alpha, \mu, b, \lambda, w, r\}$ . To allow for some substitution away from the manufacturing sector, we specify utility as a CES bundle of both the manufacturing good and a non-traded good,  $[\omega G^\eta + (1 - \omega) C_N^\eta]^{1/\eta}$ , and additionally specify fixed values for  $C$ ,  $P_N$ , and  $\omega$ . Equilibrium in this partial equilibrium setup is simply the price of output and the number of imported varieties,  $\{p_i, \Omega_i\}$ , such that the firm's first-order conditions are satisfied given final demand in the economy. The numerical algorithm used to solve for the equilibrium is detailed in the appendix.

### 5.4 Calibration

We now describe our calibration of the most important parameters used in our benchmark simulation, though we later report results for varying parameter values. We set  $\theta = \rho = 0.75$ , corresponding to an elasticity of 4, the value used in Section 3. We choose  $\mu = 2/3$ , consistent with the 1997 input-output table for Argentina obtained from the OECD.<sup>36</sup> Table 5 lists these as well as the other parameter values used in our benchmark simulation, which simulates an industrial sector with 1,000 firms.

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<sup>36</sup>The OECD input-output table contains 48 sectors of which we classify 21 as manufacturing. We find similar values for 1998–2002 using Argentina's annual manufacturing census (the *Encuesta Industrial Annual*). The stability of this share corroborates our Cobb-Douglas functional form assumption.

$\theta$	$\rho$	b	$\mu$	$\alpha$	$\lambda$	$f$	$\eta$		
0.75	0.75	1	2/3	1/3	2	0.0075	0.8		
w	r	C	$P_N$	$\omega$	$p_m^{pre}$	$\hat{p}_m$	$\gamma^{pre}$	$\gamma^{post}$	
50	50	$1 \times 10^8$	0.96	0.2	1.70	1.15	0.83	0.89	

Table 5: Baseline Simulation Parameters

We can directly measure the share of input spending on domestic goods,  $\gamma$ , for 1997 from the input-output table, but Argentina has not released a version for subsequent years. The annual manufacturing census gives annual input spending by manufacturers, though, so we can approximate  $\gamma$  in future years by assuming that the growth in manufacturing spending on imported inputs follows the growth in total imports.<sup>37</sup> This results in a pre-crisis minimum value of 0.83 for  $\gamma$  (i.e.  $\gamma^{pre} = 0.83$ ). We do not formally estimate the fixed cost function, but choose a functional form and parameterization which, in conjunction with other parameter values, both satisfies the second-order condition listed in footnote 32 and allows us to qualitatively replicate the findings from the empirical section.<sup>38</sup> Given the level of expenditures on the manufactured good, the wage, the rental rate on capital, and the fixed cost function, we choose the initial unit import price  $p_m$  to match  $\gamma^{pre}$ .

Our analysis does not require a parametric form of the productivity distribution, so we choose  $A_i$  manually, which allows us to better target various moments of the import share distribution. The dotted red line of Figure 10 plots the simulated import cdf, which is a close match with that in the solid blue line plotted from the Argentine data in 2000.<sup>39</sup>

We choose values for  $\eta$  and  $\omega$  and set the non-manufactured good price  $P_N$  so that the initial share of the manufacturing sector in total consumption spending equals about 26 percent, the level of manufacturing value added in consumption in Argentina’s national accounts prior to the recession. We then hold these and all other parameter values fixed and

<sup>37</sup>We have also tried growing imported input spending by the import spending on capital goods, intermediate goods, fuels, and parts of capital goods as reported in Argentina’s annual manufacturing census. The results do not meaningfully change.

<sup>38</sup>In the base period of our simulation, spending on the fixed cost averages about 14 percent of the total fixed and variable spending on each import. This is only a bit above the equivalent 11 percent number given as the upper end of the range in Alessandria, Kaboski, and Midrigan (2010).

<sup>39</sup>In principle, we could have tried to match every point on the cdf, but restrictions due to computational speed prevented us from doing this. We believe our match of the distribution at the 10, 20, 50, and 95 percent y-axis values is sufficient to capture the relative importance of large, medium, and small firms in our simulated economy.



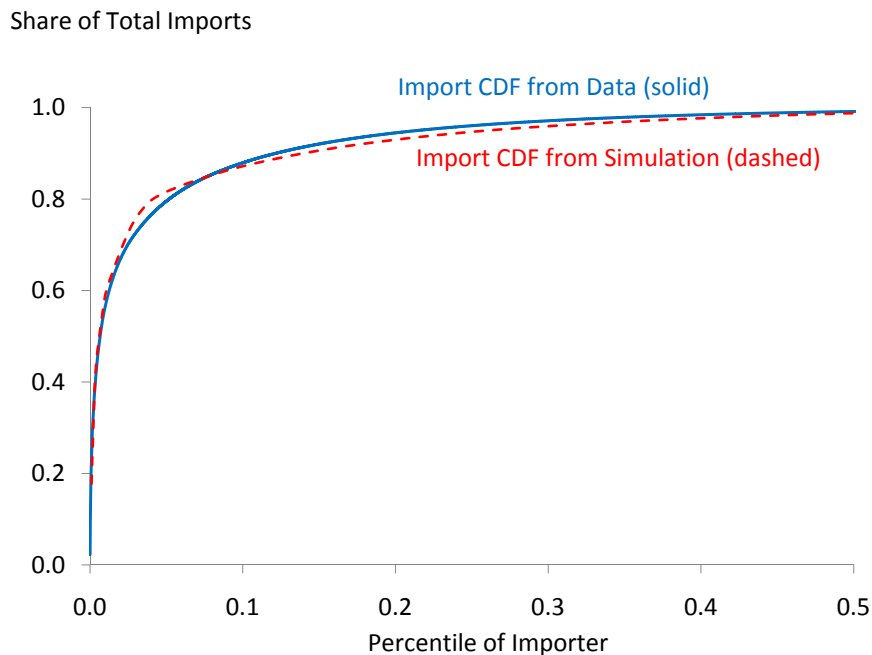


Figure 10: Concentration of Imports in the Data (2000) and in the Simulation

shock  $p_m$  such that the share of manufacturing input spending allocated to imported goods,  $1 - \gamma$ , decreases to 0.11 (i.e.  $\gamma^{post} = 0.89$ ), consistent with the 2002 value in our calculations with the Argentine data. We do not aim to explain objects outside of the manufacturing sector, such as real GDP growth. As such, the values of  $P_N$ ,  $\omega$ , and  $\eta$  are not important for our simulation other than their determination of the initial share of overall consumption spending on the manufacturing sector that uses imported inputs and the real decline in manufacturing value added.<sup>40</sup> Given these values and the shock to  $p_m$ , the implied reduction in real manufacturing value added equals 17 percent, equal to the real decline of industrial production in the Argentine national accounts over this same period.

## 5.5 Simulated Adjustment Patterns

We now simulate an import price shock in our model and report results in order to achieve three goals. First, we wish to demonstrate that the model can reproduce *Findings 2-4* (it by assumption reproduces *Finding 1*). Second, we wish to evaluate the scale of productiv-

<sup>40</sup>For example, exogenously imposing a change in aggregate final consumption  $C$  or changing the parameter  $\eta$  would be isomorphic for the objects in the manufacturing sector we focus on.

ity changes brought about from the shock. Third, we use the simulations to demonstrate the differential response of our economy, which is designed to reproduce the large product sub-extensive margin observed in our firm-level data, compared with an economy without significant extensive margin adjustments, as would be consistent with aggregate data.

*Finding 1* documented that the firm extensive margin played little role and given there is no fixed cost of importing per se (only a per-variety fixed cost), the firm extensive margin plays no role in trade adjustment in our simulated model.<sup>41</sup> Sub-extensive margin adjustment in our model, however, contributes 47 percent of the simulated decline in exports, with the remainder due to the sub-intensive margin. This compares with the sub-extensive margin contributing 45 percent and the sub-intensive margin contributing 44 percent in the data, as we showed in *Finding 2*. The sub-extensive and sub-intensive margins are comparably important with each other in both our simulated model and in the data.

*Finding 3* noted that larger firms (proxied by the size of their pre-crisis imports) exhibit on average a smaller percentage decline in trade than do smaller firms and that the sub-intensive margin played a greater role for larger firms. In the data this result is driven by the reduced prevalence of extensive and sub-extensive margin adjusters among larger firms. Figure 11 plots these moments of trade adjustment against importer size and confirms these findings hold in our simulated data. The differences between large and small firms in these respects are more muted in our simulation than in the data. This emerges in large part because we have omitted the extensive margin in our model. If we introduced a fixed importing cost which generated the exit from trade among small firms, dispersion in these figures would more closely resemble the magnitudes witnessed in the data.<sup>42</sup>

Figure 11(a) shows that larger firms in the simulation adjust less and Figure 11(b) shows that a greater share of this adjustment for the largest firms comes from the sub-intensive margin. In general the relationship between firm size and the elasticities of response to cost shocks depends on the model's details, parameter values, and distributional assumptions,

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<sup>41</sup>We could, of course, easily add an initial fixed cost to increase the role of the firm extensive margin. Because these firms will be the smallest in the economy, this change would have no meaningful impact on any other reported result.

<sup>42</sup>We also note that while only the smallest firms would adjust along the extensive margin in such an exercise, any randomness (such as technology shocks) introduced to this environment would spread these extensive margin adjusters across the size distribution.

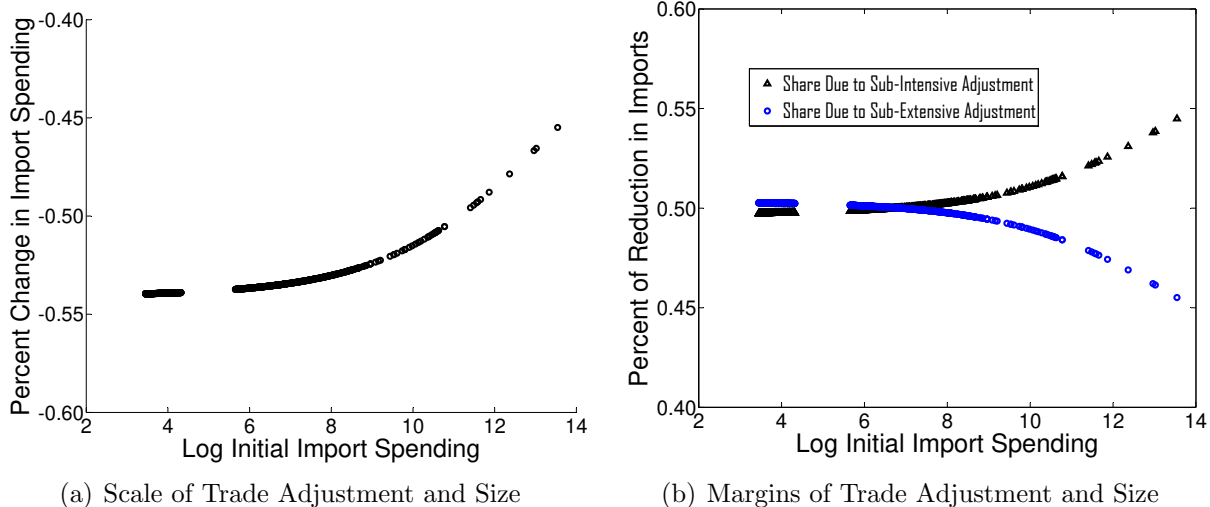


Figure 11: Adjustment and Size in Simulation

discussed further in the appendix.<sup>43</sup> In our simulation, firms with worse technology (smaller size) have a higher  $\gamma_i$ . A higher  $\gamma_i$  on one hand increases the responsiveness to a shock of the number of foreign varieties imported (because the firm with a higher  $\gamma_i$  has a higher price movement of  $P_{M_i}$  relative to  $P_{X_i}$ ). On the other hand it lowers the responsiveness to a shock of the optimal price and therefore demand, which in turn affects the demand for inputs. The first effect will dominate if:

$$\frac{\rho}{1 - \rho} > \frac{\mu\theta}{1 - \theta},$$

which is the case with our benchmark parameters.

Finally, *Finding 4* measured the implied change in the unit cost of each firm’s CES import bundle and found that a trade-weighted average of these changes ranged between 6 and 13 percent, depending on the definition of “variety” used. We calculate this identical object in our simulation and find a value of 8.9 percent, highly consistent with the empirical range. This confirms that the economic impact of the simulated sub-extensive margin adjustment also resembles that found in the firm-level data.

<sup>43</sup>In Chaney (2008) the elasticity depends on the specifics of the distribution function across imported varieties. In the case of Pareto the elasticity is shown to be invariant to firm productivity. In our setup the distribution is degenerate because all varieties are identical.

## 5.6 Simulated Baseline Declines in Manufacturing Productivity

Figure 12 shows how  $\Delta \ln \gamma_i$  and  $\Delta \ln \mathbf{PR}_i$  vary across the size distribution of firms. The firms with the best technology import the most and are at the right of the plot. Their initial  $\gamma_i$  values were lowest and the percent increase in those values is greatest. This results in the largest productivity decline for those firms



Figure 12: Changes in Domestic Input Share and Productivity

We next provide estimates of sectoral level productivity in Table 6. For each simulation, we report three values:  $\Delta \ln \mathbf{PR}$ ,  $\ln \mathbb{F}$ , and  $\Delta \ln \widetilde{\mathbf{PR}}$ . We start with results from our benchmark model with fixed costs and roundabout production, reported in row (1), which is labeled “Benchmark.” As described above, the foreign input cost shock in this simulation generates an increase in the manufacturing sector’s  $\gamma$  from 0.83 to 0.89 and generates a decline in manufacturing productivity,  $\Delta \ln \mathbf{PR}$ , of 5.5 percent. If we take into account the mismeasurement due to ignoring the 8.9 percentage point increase in import bundle prices due to dropped varieties, the magnitude of the mismeasured productivity decline,  $\Delta \ln \widetilde{\mathbf{PR}}$ , is 6.6 percent.

We now compare the productivity estimates in the benchmark simulation to those that would be obtained under alternative model assumptions and subject to the same size import

		$\Delta \ln \mathbf{PR}$	$\ln \mathbb{F}$	$\Delta \ln \widetilde{\mathbf{PR}}$
(1)	Benchmark	-0.055	0.089	-0.066
(2)	No Fixed Costs	-0.043	0.000	-0.043
(3)	No Roundabout Production	-0.026	0.119	-0.038
(4)	$\rho = 0.50$	-0.068	0.037	-0.073
(5)	$\theta = 0.90$	-0.017	0.003	-0.017
(6)	$\rho = 0.50, \theta = 0.90$	-0.028	0.0025	-0.028
(7)	Adjusting For Inventories, $\gamma^{\text{post}} = 0.86$	-0.024	0.034	-0.029
(8)	No Capital Goods, $\gamma^{\text{post}} = 0.87$	-0.033	0.049	-0.040

Table 6: Simulation Results: Productivity

price shock  $\Delta \ln p_m$  as in the benchmark case. These results are reported in rows (2)-(6) of Table 6.<sup>44</sup>

We start by comparing rows (1) and (2) to answer the question of how a shock impacts productivity in a model which incorporates a sub-extensive margin (the benchmark) compared to the identical shock in a model without one (no fixed costs). The decline in import shares is smaller in row (2) compared with that in the benchmark case in row (1), and none of the losses are associated with less import varieties. Even accounting for the savings of labor associated with declines in payment of fixed costs, welfare relevant productivity declines by 1.2 percentage points more when we take into account the sub-extensive margin. This difference roughly doubles if one considers the impact of sub-extensive margin adjustment on measured productivity. The jump from approximately zero to -4.3 percent, which comes from the move from perfect competition to imperfect competition is clearly larger than the additional movement from the sub-extensive margin. However, this margin does contribute an additional 30 percent.

<sup>44</sup>In these simulations we adjust  $P_N$  and  $p_m$  to match the initial share of spending on manufactures and  $\gamma$  to the benchmark case.

Row (3) evaluates the quantitative importance of roundabout production. We specify that the price of domestic inputs  $P_Z$  is fixed at the same initial value as in the benchmark simulation and is completely insensitive to changes in the import price  $p_m$ . All other features of the model are the same as in the benchmark case. In this environment firms will substitute more than in our benchmark case to the domestically produced intermediate inputs. The increase in unit cost of production is therefore lower and manufacturing value added falls by less than in the benchmark case. The resulting productivity decline of 2.6 percent is roughly half the magnitude of the decline in the benchmark case, even though both simulations are calibrated to the same initial conditions and are exposed to the same shock. This highlights the importance of this mechanism for amplifying the shock.

## 5.7 Robustness

In this sub-section, we re-simulate our system with a number of different parameter values or assumptions used in our empirical analysis to determine the sensitivity of our productivity and welfare estimates. The results are reported in rows (4)-(8) of Table 6.

Rows (4) through (6) evaluate the sensitivity to the key elasticity parameters  $\rho$  and  $\theta$ . Feenstra, Obstfeld, and Russ (2010), in a model with very similar structure to ours, emphasize estimates suggesting  $\rho < \theta$ . We consider this possibility by simulating the model with  $\rho = 0.5$ , corresponding to an elasticity between domestic and foreign varieties of 2. Because the importance of the sub-extensive margin is decreasing in  $\rho$  the decline in productivity in response to the same shock is larger than the benchmark case and close to 7%. Row (5) shows that productivity declines by 1.7 percent if we increase  $\theta$  to 0.90, corresponding to a high elasticity within domestic and within foreign varieties of 10. Row (6) shows that the combination of making the between-elasticity lower and the within-elasticity higher yields a productivity decline of about 2.8 percent.

Next, we consider the impact of inventories. As shown in Figure 8, the Argentine firms in industries which appear to hold the least inventories relative to their sales reduced their imports by significantly less than typical firms. If we re-calculate the value in the 2002 Argentine data of the aggregate share of input spending on domestic goods  $\gamma$  under the

assumption that aggregate import growth is scaled down to match the experience of these least inventory intensive sectors, we obtain the value  $\gamma^{post} = 0.86$  rather than the benchmark post-crisis value of 0.89. We therefore introduce a simulated decline in the import price of a magnitude that generates this more limited movement in  $\gamma$ . Row (7) reports that this produces a productivity decline that is a bit less than half as large as that seen in the benchmark case but which we still consider to be economically significant. Relatedly, row (8) considers a shock that is calibrated to the change in  $\gamma$  found in the data when we exclude import spending on capital goods. This implies a value for  $\gamma^{post}$  equal to 0.87 and a productivity decline of 3.3 percentage points.

In sum, we find that an imported input cost shock generates meaningful declines in productivity across several specifications.

## 6 The Decline and Recovery of TFP in Argentina

We have demonstrated how aggregate productivity can decline as firms substitute from imported to domestic input use. The shift in spending toward domestic sources is captured by movement in  $\gamma$ , while the importance of dropped import varieties for raising firm unit costs is captured by  $\mathbb{F}$ . In this section we correlate our measures of changes in  $\gamma$  and  $\mathbb{F}$  with independent estimates of TFP for Argentina. These independent TFP estimates differ slightly from the welfare-relevant measure of productivity we use in this paper, but the basic time-series properties of these should be similar. We show that the chronology of our  $\gamma$  and  $\mathbb{F}$  measures is consistent with the chronology of TFP movements, both during the period when TFP declined and when it recovered.

Figure 13 includes plots of two estimates of productivity in Argentina as measured by ARKLEMS, an Argentine project that measures productivity following the methodology of the WORLD KLEMS initiative and of Coremberg (2009). The solid black line plots “unadjusted” TFP, which the author says corresponds to the typical methodology used in Argentine and Latin American TFP estimation as well as by other studies such as Kydland and Zarazaga (2002). The blue dashed line plots what they label “strict” TFP, which includes

adjustments of labor quality and capital utilization.<sup>45</sup> We should point out that the adjusted TFP measure is done with limited data and restrictive assumptions and may therefore be less reliable.

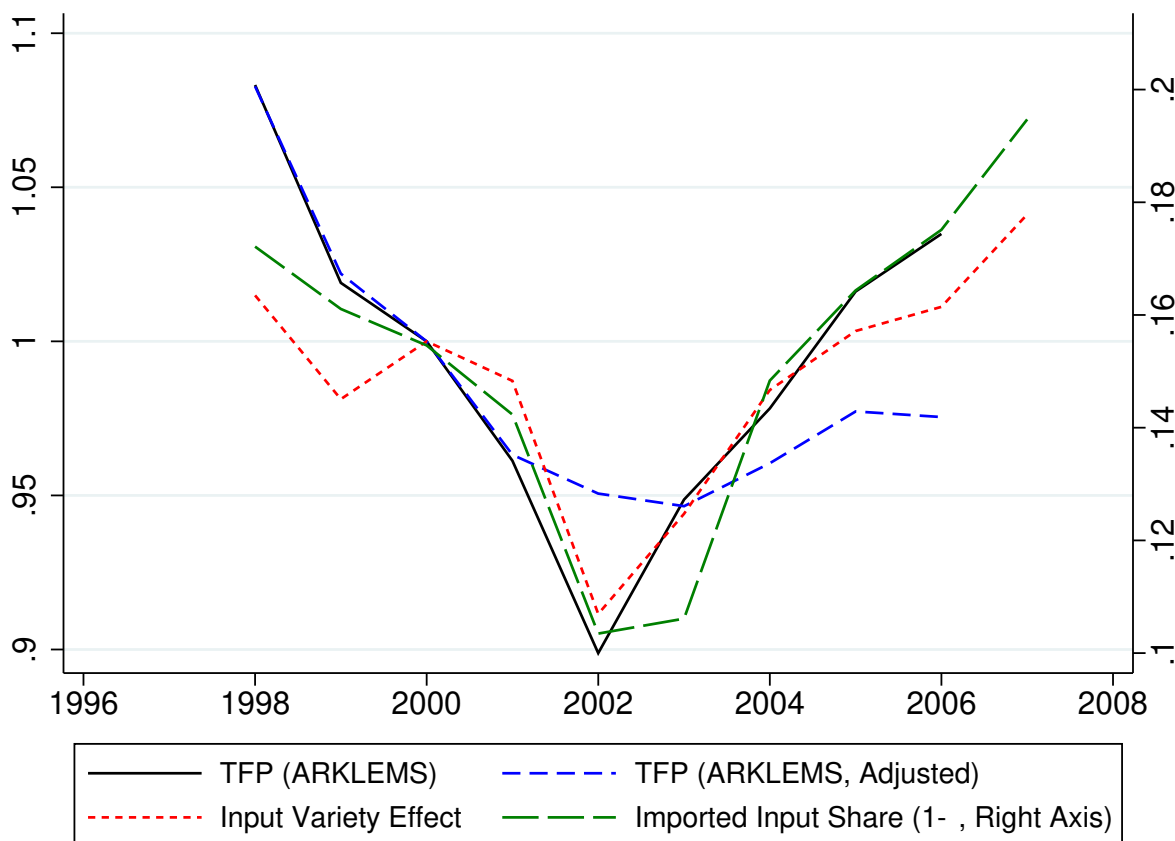


Figure 13: Time-series Paths of Productivity, Dropped Varieties, Import Shares

Both TFP series are normalized to equal 1 in 2000 and indicate that TFP began to decline in 1999. The unadjusted series exhibits moderate to large declines through 2001, with its largest decline occurring in 2002. A rapid recovery of this measure of TFP then begins in 2003. The adjusted series declines more modestly in 2002 and continues this decline in 2003 before exhibiting a more mild recovery in 2004 and 2005. The unadjusted TFP series finishes 2006 (the last available ARKLEMS estimate) only slightly below its pre-recession level while

<sup>45</sup>We do not plot the TFP measures from Sandleris and Wright (2011) here as those estimates end in 2002. Our results are consistent with their estimate from continuing establishments, the relevant comparison group for us because all of the adjustment in trade takes place within continuing firms. This measure of TFP declines most steeply in 2001 but continues to meaningfully decline in 2002.



the adjusted series remains depressed.

The long-dashed green line plots our estimates of  $(1 - \gamma)$ , the share of imported inputs in total input spending. The decline in  $(1 - \gamma)$  from a peak of 0.17 to the trough value of 0.11 corresponds to the values in Table 5 of  $\gamma^{pre} = 0.83$  and  $\gamma^{post} = 0.89$ . Though much of the substitution away from imported inputs occurs in very late 2001 and 2002 due to movement in the exchange rate, this substitution in fact started as early as 1999. This is consistent with our model because in the presence of fixed costs of importing, firms will spend less on imported inputs as total demand declines, even holding fixed the relative price of imports. The series stabilizes in 2003 and then recovers starting in 2004.<sup>46</sup>

The short-dashed red line plots our estimates of the impact of dropped import varieties on the unit cost of production  $\mathbb{F}$  using the same methodology as those done in Table 4. We consider idiosyncratic firm-specific changes in the cost of imported inputs in each year relative to the base year of 2000 due to changes in the mix of 10-digit inputs by country of origin. This series has a small decline in 2001, a larger decline in 2002, and a recovery starting in 2003.<sup>47</sup> The time variation in  $\mathbb{F}$  therefore displays a positive correlation with that of TFP.

While clearly there were many other negative shocks during the Argentine crisis, the time-series patterns do offer corroboration that the mechanisms highlighted in our paper may well have been salient for TFP in Argentina over this period.

## 7 Conclusion

Two prominent features of large macroeconomic crises are the collapse in imports and the large decline in measured TFP. We use transaction-level trade data from the Argentine crisis of 2001–2002 to characterize, mechanically, how this reduction in trade occurred and how

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<sup>46</sup>Calculation of the imported input share in this plot differs slightly from the methodology described in Section 5.3 because we need data for years for which annual manufacturing censuses are not available. We therefore use data from the World Bank’s World Development Indicators to compare growth in manufacturing spending on imports to growth in manufacturing value added, rather than total input spending, in order to grow the earlier series forward. This implicitly assumes that, as in the model, the ratio of spending on inputs to the sector’s value added remains constant. We compared estimates of  $\gamma$  for 1998–2003 using this new methodology to estimates using that described in Section 5.3 and found them to be highly similar.

<sup>47</sup>In fact, this measure also shows a small downward trend from 1998 to 2000, but less confidence should be placed in the 1998 and 1999 values for this measure due to the gap in our data over this period.

the decline influences a welfare-relevant measure of productivity. We find that the extensive margin of trade at the country level, where previous importers stop importing or product varieties are dropped by all importers, is not quantitatively significant. However, the micro-data allow us to observe quantitatively significant within-firm churning of inputs that we call the sub-extensive margin. Finally, the scale and type of trade adjustment differs with the size of the importer, generating heterogeneous changes in their unit costs of production.

Motivated by these empirical findings, we build a heterogeneous firm model with roundabout production and fixed costs of importing. The model replicates the above empirical findings and generates economically significant declines in productivity. When calibrated to reproduce the lack of extensive margin adjustment observable in aggregate data, the impact on productivity differs meaningfully.

Crises such as the one Argentina experienced surely involve multiple shocks, and no one channel can explain its entire economic impact. Our analysis suggests, however, that the reduced use of imported intermediate inputs is a significant contributor to the productivity and welfare losses experienced during crises.

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## Appendices – Not for Publication

### Appendix A: Derivation of Equations for Productivity

#### Derivation of Equation (8)

The derivation is very similar to Basu and Fernald (2002) with the distinction that we have labor that is used in fixed costs. The production function for each firm is given by equation (3). Since firms are price takers in the primary factor and intermediate input markets and set prices as a constant markup  $1/\theta$  over marginal cost, we have:

$$p_i \frac{\partial Y_i}{\partial L_{p,i}} = \frac{w}{\theta}, p_i \frac{\partial Y_i}{\partial K_i} = \frac{r}{\theta}, p_i \frac{\partial Y_i}{\partial X_i} = \frac{P_{X_i}}{\theta}.$$

To measure the growth rate of value added we use the convention Divisia index formula:

$$\Delta \ln Y_i^{VA} = \frac{\Delta \ln Y_i - s_X^Y \Delta \ln X_i}{1 - s_X^Y} = \Delta \ln Y_i - \frac{s_X^Y}{1 - s_X^Y} (\Delta \ln X_i - \Delta \ln Q_i),$$

where  $s_X^Y$  is the *revenue* share of intermediates,  $s_X^Y = \frac{P_{X_i} X_i}{P_i Y_i}$ , which is equal to the constant  $\mu\theta$ . We can then write:

$$\begin{aligned} \Delta Y_i &= \frac{\partial Y_i}{\partial K_i} \Delta K_i + \frac{\partial Y_i}{\partial L_{p,i}} \Delta L_i^p + \frac{\partial Y_i}{\partial X_i} \Delta X_i + \frac{\partial Y_i}{\partial A_i} \Delta A_i, \\ \Delta \ln Y_i &= \frac{(1 - s_{X_i}^Y)}{\theta} s_{k,i} \Delta \ln K_i + \frac{(1 - s_{X_i}^Y)}{\theta} \omega_{L^p} s_{L_i} \Delta \ln L_i^p + \frac{s_{X_i}^Y}{\theta} \Delta \ln X_i + \frac{F_{A_i} A_i}{Y_i P_i} \Delta \ln A_i. \end{aligned}$$

This follows from the relation  $s_{k,i} = \frac{s_{k,i}^Y}{(1 - s_{X_i}^Y)}$  and  $\omega_{L^p} \equiv \frac{L_i^p}{L_i}$ . Rearranging, we get:

$$\begin{aligned} \Delta \ln Y_i^{VA} &\equiv \Delta \ln Y_i - \frac{s_X^Q}{1 - s_X^Q} (\Delta \ln X_i - \Delta \ln Y_i) \\ &= \frac{(1 - \mu\theta)}{\theta(1 - \mu)} [s_{k,i} \Delta \ln K_i + \omega_{L^p} s_{L_i} \Delta \ln L_i^p] \\ &\quad + \frac{\mu\theta}{1 - \mu\theta} \left[ \frac{(1 - \mu\theta)}{\theta(1 - \mu)} - 1 \right] (\Delta \ln X_i - \Delta \ln Y_i) + \frac{F_{A_i} A_i}{(1 - \mu) Y_i P_i} \Delta \ln A_i. \end{aligned}$$

Finally, define the welfare relevant firm-level productivity using the modified Solow Residual:

$$\begin{aligned} \Delta \ln \mathbf{PR}_{it} &= \Delta \ln Y_i^{VA} - s_{k,i} \Delta \ln K_i - s_{l,i} \Delta \ln L_i \\ &= \Delta \ln Y_i^{VA} - s_{k,i} \Delta \ln K_i - s_{l,i} \omega_{L^p} \Delta \ln L_i^p - s_{l,i} (1 - \omega_{L^p}) \Delta \ln L_i^F. \end{aligned}$$

Substituting for  $\Delta \ln Y_i^{VA}$ , we arrive immediately at equation (8).

#### Derivation of Expressions (9)-(12)

We present the derivation in the following steps:

**Step 1:** We express  $\Delta \ln X_i - \Delta \ln Y_i$  as a function of  $\gamma_i$ . It follows from equations (4), (5), and  $p_i = C_i/\theta$ , given fixed  $w$  and  $r$ , that:

$$\Delta \ln X_i - \Delta \ln Y_i = \Delta \ln p_i - \Delta \ln P_{X_i} = (\mu - 1) \Delta \ln P_{X_i}.$$

Following the definition of  $\gamma_i$ , we write:

$$\gamma_i = \frac{P_Z Z_i}{P_{X_i} X_i} = \left( \frac{P_Z}{P_{X_i}} \right)^{\frac{\rho}{\rho-1}},$$

$$P_{X_i} = P_Z \gamma_i^{\frac{1-\rho}{\rho}},$$

and

$$\begin{aligned} P_Z &= \left[ \int_i p_i^{\frac{\theta}{\theta-1}} di \right]^{\frac{\theta-1}{\theta}} = \left[ \int_i \left( \frac{C_i}{\theta} \right)^{\frac{\theta}{\theta-1}} di \right]^{\frac{\theta-1}{\theta}} = \left[ \int_i \left( \frac{(r^\alpha w^{1-\alpha})^{1-\mu} P_{X_i}^\mu}{\epsilon \theta A_i} \right)^{\frac{\theta}{\theta-1}} di \right]^{\frac{\theta-1}{\theta}} \\ &= \frac{(r^\alpha w^{1-\alpha})^{1-\mu}}{\epsilon \theta} \left[ \int_i \left( P_Z \gamma_i^{\frac{1-\rho}{\rho}} \right)^{\frac{\mu \theta}{\theta-1}} A_i^{\frac{\theta}{1-\theta}} di \right]^{\frac{\theta-1}{\theta}} \\ &= \frac{(r^\alpha w^{1-\alpha})^{1-\mu} P_Z^\mu}{\epsilon \theta} \underbrace{\left[ \int_i \gamma_i^{\mu \left( \frac{\rho-1}{\rho} \right) \frac{\theta}{1-\theta}} A_i^{\frac{\theta}{1-\theta}} di \right]^{\frac{\theta-1}{\theta}}}_{Q_{\gamma\theta\rho}^{-1}}, \end{aligned}$$

where  $\epsilon = \mu^\mu (1-\mu)^{1-\mu} (\alpha^\alpha (1-\alpha)^{1-\alpha})^{1-\mu}$ . We can then write:

$$P_Z = \frac{(r^\alpha w^{1-\alpha})}{(\epsilon \theta)^{\frac{1}{1-\mu}}} Q_{\gamma\theta\rho}^{-\frac{1}{1-\mu}},$$

$$P_{X_i} = \frac{(r^\alpha w^{1-\alpha})}{(\epsilon \theta)^{\frac{1}{1-\mu}}} Q_{\gamma\theta\rho}^{-\frac{1}{1-\mu}} \gamma_i^{\frac{1-\rho}{\rho}},$$

and

$$\Delta \ln P_{X_i} = \frac{1}{\mu-1} \Delta \ln Q_{\gamma\theta\rho} + \frac{1-\rho}{\rho} \Delta \ln \gamma_i. \quad (13)$$

**Step 2:** The firm's decision for use of  $L^F$  is related to its decision on  $\Omega$ . The firm maximizes:

$$\begin{aligned} \tilde{\Pi}_i &= \Pi_i - w L^F \\ &= (1-\theta) P_i Y_i - w L^F, \end{aligned}$$

subject to:

$$Y_i = g_i + \int_j z_{ji} dj = \left( \frac{p_i}{P_G} \right)^{\frac{1}{\theta-1}} G + \int_j \left( \frac{p_i}{P_Z} \right)^{\frac{1}{\theta-1}} \left( \frac{P_Z}{P_{X_j}} \right)^{\frac{1}{\rho-1}} X_j dj.$$

We define:

$$\tilde{D} \equiv \left(\frac{1}{P_G}\right)^{\frac{1}{\theta-1}} G + \int_j \left(\frac{1}{P_Z}\right)^{\frac{1}{\theta-1}} \left(\frac{P_Z}{P_{X_j}}\right)^{\frac{1}{\rho-1}} X_j dj,$$

and write:

$$\Pi_i = (1 - \theta) p_i Y_i = (1 - \theta) p_i^{\frac{\theta}{\theta-1}} \tilde{D}.$$

The FOC for  $\Omega_i$  is:

$$\frac{\partial \Pi_i}{\partial \Omega_i} = w \frac{\partial L^F}{\partial \Omega_i},$$

which gives the following expressions:

$$\ln \Pi_i = \ln(1 - \theta) + \frac{\theta}{\theta - 1} \ln p_i + \ln \tilde{D},$$

$$\frac{1}{\Pi_i} \frac{\partial \Pi_i}{\partial \Omega_i} = \frac{\theta}{\theta - 1} \frac{\partial \ln p_i}{\partial \Omega_i} = \mu \frac{\partial \ln P_{X_i}}{\partial \Omega_i} = \frac{\theta - 1}{\theta} \left(\frac{P_{M_i}}{P_{X_i}}\right)^{\frac{\rho}{\rho-1}} \frac{1}{\Omega_i},$$

$$\frac{\partial \Pi_i}{\partial \Omega} = \frac{\Pi_i \mu (1 - \gamma_i)}{\Omega} = w f_v \lambda \Omega_i^{\lambda-1},$$

$$\Pi_i \mu (1 - \gamma_i) = w f_v \lambda \Omega_i^\lambda = w \lambda L_i^F,$$

$$w L_i^F = \lambda^{-1} (1 - \theta) P_i Y_i \mu (1 - \gamma_i),$$

$$w L_i^P = (1 - \mu)(1 - \alpha) \theta P_i Y_i,$$

$$\frac{w L_i^P}{w L_i^F} = \frac{L_i^P}{L_i^F} = \frac{(1 - \mu)(1 - \alpha) \theta P_i Y_i}{\lambda^{-1} (1 - \theta) P_i Y_i \mu (1 - \gamma_i)} = \frac{(1 - \mu)(1 - \alpha) \theta}{\lambda^{-1} (1 - \theta) \mu (1 - \gamma_i)},$$

and

$$\frac{L_i^P}{L_i^F} = \frac{(1 - \mu)(1 - \alpha) \theta}{\lambda^{-1} (1 - \theta) \mu (1 - \gamma_i)}.$$

As  $\gamma_i$  and  $\lambda$  increase, so does the share of labor that is used for production. This is used to arrive at the expression for  $\omega_{L_i^P}$ :

$$1 - \omega_{L_i^P} = \frac{L_F}{L} = \frac{w L_i^F}{w L_i^F + w L_i^P} = \frac{\lambda^{-1} (1 - \theta) \mu (1 - \gamma_i)}{\lambda^{-1} (1 - \theta) \mu (1 - \gamma_i) + (1 - \mu)(1 - \alpha) \theta}.$$

**Step 3:** Express  $\Delta \ln F$  as a function of  $P_{X_i}$ . We write:

$$\Delta \ln L^F = \lambda \Delta \ln \Omega_i = \lambda \frac{\theta}{\theta - 1} (\Delta \ln P_{M_i} - \Delta \ln p_m),$$

$$\ln(1 - \gamma_i) = \frac{\rho}{\rho - 1} [\ln P_{M_i} - \ln P_{X_i}],$$

$$\ln P_{M_i} = \ln P_{X_i} - \frac{1 - \rho}{\rho} \ln(1 - \gamma_i),$$



$$\begin{aligned}\Delta \ln L^F &= \lambda \Delta \ln \Omega_i = \lambda \frac{\theta}{\theta - 1} \left( \Delta \ln P_{X_i} - \frac{1 - \rho}{\rho} \Delta \ln(1 - \gamma_i) - \Delta \ln p_m \right), \\ s_{L,i} &= \frac{wL_i^P + wL_i^F}{P_i^{VA} Y_i^{VA}} = \frac{\lambda^{-1}(1 - \theta)\mu(1 - \gamma_i) + (1 - \mu)(1 - \alpha)\theta}{(1 - \mu\theta)}, \\ s_{li}(1 - \omega_{lp}) \Delta \ln L^F &= \frac{\lambda^{-1}(1 - \theta)\mu(1 - \gamma_i)}{(1 - \mu\theta)} \Delta \ln L^F,\end{aligned}$$

and

$$\begin{aligned}\frac{(1 - \mu\theta)}{\theta(1 - \mu)} s_{li}(1 - \omega_{lp}) \Delta \ln L^F &= \frac{(1 - \mu\theta)}{\theta(1 - \mu)} \frac{\lambda^{-1}(1 - \theta)\mu(1 - \gamma_i)}{(1 - \mu\theta)} \Delta \ln L^F \\ &= -\frac{\mu(1 - \gamma_i)}{(1 - \mu)} \left[ \Delta \ln P_{X_i} - \frac{1 - \rho}{\rho} \Delta \ln(1 - \gamma_i) - \Delta \ln p_m \right].\end{aligned}$$

**Step 4:** Replace the expression for  $\Delta \ln P_{X_i}$  from equation (13) in the preceding equation. Replacing the above terms in the expression for firm-level productivity, equation (8), and aggregating over all  $i$  using firm value-added shares  $\omega_i$ , we arrive at an expression for aggregate productivity.

The last step is to relate changes in  $\Delta \ln Q_{\gamma\theta\rho}$  to changes in  $\omega_i$  and  $\gamma_i$ . We start with an expression for the value-added weights (which should relate market shares of each firm to technologies and trade shares:

$$\omega_i = \left( \frac{p_i}{\left( \int_j (p_j)^{\frac{\theta}{\theta-1}} dj \right)^{\frac{\theta-1}{\theta}}} \right)^{\frac{\theta}{\theta-1}} = \left( \frac{(\gamma_i)^{\mu \frac{1-\rho}{\rho}} (A_i)^{-1}}{\left( \int_j (\gamma_j)^{\mu \frac{1-\rho}{\rho} \frac{\theta}{\theta-1}} (A_j)^{-\frac{\theta}{\theta-1}} dj \right)^{\frac{\theta-1}{\theta}}} \right)^{\frac{\theta}{\theta-1}}.$$

We then substitute in using our expression for  $Q$ :

$$Q_{\gamma\theta\rho} = \left[ \int_i \gamma_i^{\mu \frac{\theta}{\theta-1} \frac{1-\rho}{\rho}} (A_i)^{\frac{\theta}{1-\theta}} di \right]^{\frac{1-\theta}{\theta}} = (\omega_i)^{\frac{\theta-1}{\theta}} A_i (\gamma_i)^{\mu \frac{\rho-1}{\rho}},$$

and write:

$$\Delta \ln Q_{\gamma\theta\rho} = \frac{\theta - 1}{\theta} \sum_i \omega_i \Delta \ln \omega_i + \mu \frac{\rho - 1}{\rho} \sum_i \omega_i \Delta \ln \gamma_i,$$

given  $\Delta \ln A_i = 0$ .

The final expressions (9)-(12) are arrived at through substitution and regrouping these terms and using the approximation  $\Delta \ln(1 - \gamma_i) = -\frac{\gamma_i}{1 - \gamma_i} \Delta \ln \gamma_i$ , which is valid for small shocks. In the simulation section we do not use this approximation because we study large shocks.

## Appendix B: Numerical Algorithm

The algorithm works as follows. Firms start with an initial assumption about the prices of the domestic input bundle  $P_Z^0$  and the final good  $P_G^0$ . Since the importing behavior of each firm determines its marginal cost and thereby influences  $P_Z$  and  $P_G$ , this assumption is effectively equivalent to taking as given all other firms' importing decisions. Holding these price aggregates fixed, each firm  $i$  simultaneously chooses the optimal number of imported varieties  $|\Omega_i^1|$ .<sup>48</sup> With this new set of import variety choices  $\{\Omega_i^1\}$ , we must solve a fixed point problem to find a consistent set of new prices  $\{p_i^1\}$  because each firm's marginal cost is a function of all other firms' prices due to roundabout production. In particular, we iterate the system:

$$p_i^1 = \frac{1}{A_i} \frac{1}{\theta} \frac{P_V^{1-\mu}}{\mu^\mu (1-\mu)^{1-\mu}} \left[ (P_Z^1)^{\frac{\theta-1}{\theta}} + \left( p_m |\Omega_i^1|^{\frac{\theta-1}{\theta}} \right)^{\frac{\rho}{\rho-1}} \right]^{\mu \frac{\rho-1}{\rho}}$$

$$P_Z^1 = \left( \int_i (p_i^1)^{\frac{\theta}{\theta-1}} di \right)^{\frac{\theta-1}{\theta}},$$

for all firms  $i$  until the set of prices  $\{p_i^1\}$  is consistent with the domestic input price index  $P_Z^1$  and with all firms' choices of imported varieties  $\{\Omega_i^1\}$ . We then repeat this algorithm, with firms taking as given the price indices  $P_Z^1$  and  $P_G^1$ , and generate a new set of prices and import varieties  $\{p_i^2, \Omega_i^2\}$  and price indices  $\{P_Z^2, P_G^2\}$ . We continue this process until  $\{p_i^j, \Omega_i^j\} = \{p_i^{j-1}, \Omega_i^{j-1}\}$  up to a very small tolerance.

## Appendix C: Comparative Statics of the Firm's Trade Response

In this appendix, we evaluate how each firm's response to the terms of trade shock will differ based on its pre-shock level of total imports. The intent here is to derive an expression that provides some intuition for the results in the text and as such we do not provide a formal proof. We have shown that as long as  $\lambda$  is sufficiently high, the number of imported varieties is increasing in the firm's exogenous technology  $A_i$ . Given their relative cost advantage, firms with higher  $A_i$  have lower prices  $p_i$  and consequently sell more and have higher  $Y_i$ . These are also the firms with the lowest  $\gamma_i$  (since  $P_{M_i}/P_Z$  is lower) and the highest  $M_i$ .

The elasticity of the response in  $\gamma_i$  to the import price change is a function of the initial  $\gamma_i$ . Using the definition of  $\gamma_i$  we can show that:

$$\begin{aligned} \frac{\partial \ln \gamma_i}{\partial \ln p_m} &= \frac{\rho(1-\gamma_i)}{1-\rho} \left( \frac{\partial \ln P_{M_i}}{\partial \ln p_m} - \frac{\partial \ln P_Z}{\partial \ln p_m} \right) \\ &= \frac{\rho(1-\gamma_i)}{1-\rho} \left( 1 - \frac{\partial \ln P_Z}{\partial \ln p_m} + \frac{\theta-1}{\theta} \frac{\partial \ln \Omega_i}{\partial \ln p_m} \right) > 0, \end{aligned}$$

<sup>48</sup>Though our firms have finite market shares, they ignore the impact of their own price changes on the aggregate price index. This is not problematic because the largest firm in our benchmark calibration has a market share of only 5 percent.

and

$$\frac{\partial \ln \Omega_i}{\partial \ln p_m} = \frac{\left(\frac{\theta\mu}{\theta-1} - \frac{\rho}{\rho-1}\right) \left[\gamma_i \frac{\partial \ln P_Z}{\partial \ln p_m} + (1 - \gamma_i)\right] + \frac{\rho}{\rho-1} + \frac{\partial \ln \tilde{D}}{\partial \ln p_m}}{\left(\lambda - \mu + \left(\mu - \frac{\rho}{1-\rho} \frac{1-\theta}{\theta}\right) \gamma_i\right)}.$$

For the second order conditions for an interior solution to  $\Omega_i$  to hold, the denominator must satisfy  $\left(\lambda - \mu + \left(\mu - \frac{\rho}{1-\rho} \frac{1-\theta}{\theta}\right) \gamma_i\right) > 0$ . As long as the numerator is negative and  $\frac{\partial \ln P_Z}{\partial \ln p_m} < 1$  (which is not always the case), firms increase the share spent on domestic inputs,  $\gamma_i$ , when import prices increase. To see how this elasticity varies across existing importers, we write:

$$\frac{\partial \left(\frac{\partial \ln \gamma_i}{\partial \ln p_m}\right)}{\partial \gamma_i} = -\frac{\rho}{1-\rho} \left(1 - \frac{\partial \ln P_Z}{\partial \ln p_m} + \frac{\theta-1}{\theta} \left[\frac{\partial \ln \Omega_i}{\partial \ln p_m} - (1 - \gamma_i) \frac{\partial \left(\frac{\partial \ln \Omega_i}{\partial \ln p_m}\right)}{\partial \gamma_i}\right]\right).$$

As long as the parameters are such that  $\frac{\partial \ln P_Z}{\partial \ln p_m} < 1$  and  $\frac{\partial \ln \Omega_i}{\partial \ln p_m} < 0$ , the sign of this expression depends on  $\partial \left(\frac{\partial \ln \Omega_i}{\partial \ln p_m}\right) / \partial \gamma_i$ , which measures how the elasticity of the sub-extensive margin varies with  $\gamma_i$ . If  $\partial \left(\frac{\partial \ln \Omega_i}{\partial \ln p_m}\right) / \partial \gamma_i > 0$ , indicating that the elasticity of the sub-extensive margin decreases with the initial  $\gamma_i$ , then we know that  $\partial \left(\frac{\partial \ln \gamma_i}{\partial \ln p_m}\right) / \partial \gamma_i < 0$ , implying that larger importers will change their import share by a greater percentage following an import price shock. If on the other hand  $\partial \left(\frac{\partial \ln \Omega_i}{\partial \ln p_m}\right) / \partial \gamma_i < 0$ , then the net effect depends on whether the direct effect of a lower  $\gamma$  on raising the percent change in  $\gamma$  exceeds the indirect effect that raises the relative price of the optimal import bundle relative to domestic inputs by less.

We can write  $\partial \left(\frac{\partial \ln \Omega_i}{\partial \ln p_m}\right) / \partial \gamma_i$  as:

$$\frac{\partial \left(\frac{\partial \ln \Omega_i}{\partial \ln p_m}\right)}{\partial \gamma_i} = \frac{1}{\varkappa_i^2} \left(\frac{\rho}{1-\rho} - \frac{\mu\theta}{1-\theta}\right) \left[(\mu - \lambda) \left(1 - \frac{\partial \ln P_Z}{\partial \ln p_m}\right) + \frac{1-\theta}{\theta} \left(\frac{\mu\theta}{\theta-1} + \frac{\partial \ln \tilde{D}}{\partial \ln p_m}\right)\right],$$

where

$$\varkappa_i \equiv \left(\lambda - \mu + \left(\mu - \frac{\rho}{1-\rho} \frac{1-\theta}{\theta}\right) \gamma_i\right).$$

$\frac{\partial \ln P_Z}{\partial \ln p_m}$  and  $\frac{\partial \ln \tilde{D}}{\partial \ln p_m}$  do not vary with  $\gamma_i$ . As long as  $\frac{\partial \ln P_Z}{\partial \ln p_m} < 1$  and  $\lambda$  is sufficiently large, the sensitivity to  $\gamma_i$  depends on whether  $\left(\frac{\rho}{1-\rho} - \frac{\theta\mu}{1-\theta}\right)$  is positive or negative.

## Appendix D: Additional Empirical Analyses

In this appendix, we consider two additional empirical analyses. First, we study the cross-section of manufacturing industries. Next, we consider changes in the frequency with which dropped input varieties are permanently dropped.

Starting with the cross-sectional analysis, we focus on within-manufacturing variation because trade may plausibly account for important variation in productivity. Differences in the

productivity declines of the finance and government sectors, for example, would likely have little to do with trade. The Argentine Annual Manufacturing Census includes information on value-added and the number of salaried workers in roughly 20 2-digit industries.

We combine this with information (also from the Argentine national statistics) on producer prices in those same 2-digit industries to construct growth in real value-added per worker. This is a proxy for total factor productivity at the sector level. Next, we use the information from the Capital IQ database on each firm's Primary Sector to classify some of them as belonging to these 2-digit industries (some sectors do not match and are excluded). Finally, we combine (1) the implied growth in imports for each manufacturing subsector from our data with (2) information on initial sector levels of  $\gamma$  from the 1997 input-output table and with (3) growth in total sectoral intermediate spending from the census to obtain a time-series for sectoral  $\gamma$ . This is essentially the same method used to determine changes in  $\gamma$  for the overall manufacturing sector in our calibration.

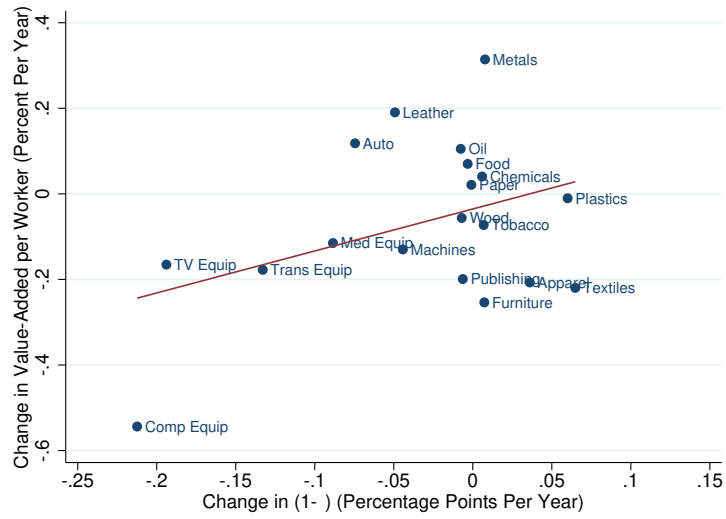
Figures 14(a) and 14(b) show the resulting relationship between changes in this measure of productivity and in the share of input spending on imports ( $1 - \gamma$ ) for the period 2000-2002. Figure 14(a) shows this plot for all sub-sectors with available data, but we note that some of these data points can reflect as few as two firms each.

Figure 14(b) shows this relationship when including only those sectors with at least 20 matched firms. Both figures suggest that shifts in intermediate spending from imported inputs toward domestic inputs correlate with measured productivity declines, though the relationship is clearly noisy and sensitive to rules on the treatment of outliers. Given this sensitivity, and given this is not our preferred welfare-relevant productivity measure, we consider this evidence less compelling and robust than the results in the primary paper and for that reason only include them in this Appendix.

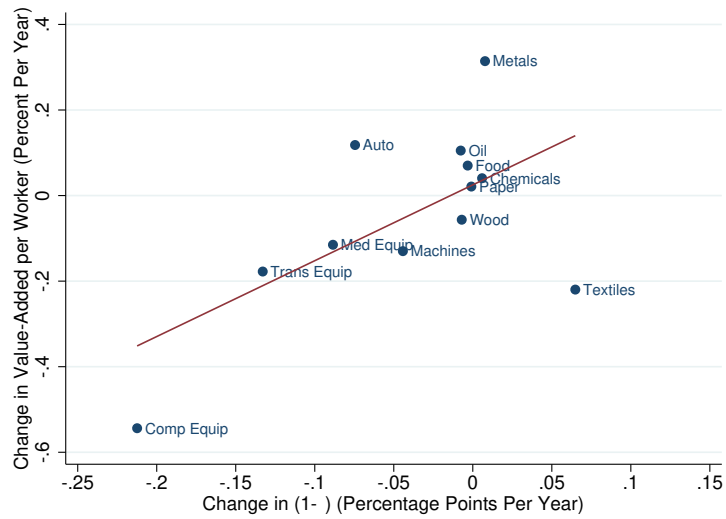
Next, we consider the share of dropped varieties that are permanently dropped as a way to address concerns that inventoried varieties are used for production. In the paper, in part to deal with this concern, we focus on a 2 year period. This is a horizon much longer than that typically used by forecasters to describe the inventory cycle. But we additionally find it useful here to measure the share of all firm and import variety combinations from the previous period that are permanently dropped (i.e. permanent sub-extensive margin adjustment) in the current period.

A variety is defined as HTS10xCountry and is considered to be permanently dropped if the firm does not again import it through 2008 (we cannot go back earlier in the analysis due to the gaps in our data in 1999, as discussed in the paper.) In this analysis, we only consider firms that imported at least 1 dollar of some good sometime after 2006 and therefore exclude all firms which permanently exited trade. This is a conservative treatment of these extensive margin adjusters, which, if included, would increase the set of permanently dropped goods.

The share of varieties that are permanently dropped is plotted in Figure 15. Early in the crisis, the line jumps above 0.2, indicating that more than one-fifth of all previous importer-variety combinations are permanently dropped, a level far in excess of anything seen before or after the crisis. Our analysis does not require that varieties are permanently dropped, but this nonetheless confirms that not only did the number of dropped varieties spike dramatically upward during the beginning quarters of the crisis (as shown in the paper), but many of those dropped varieties are permanently dropped. While this does not eliminate a possible role for inventories in smoothing the use of input varieties, it limits the extent to which inventories could have substituted for these dropped varieties.



(a) All Sectors



(b) Sectors with at Least 20 Firms

Figure 14: Sectoral Input Sourcing and Productivity, 2000-2002

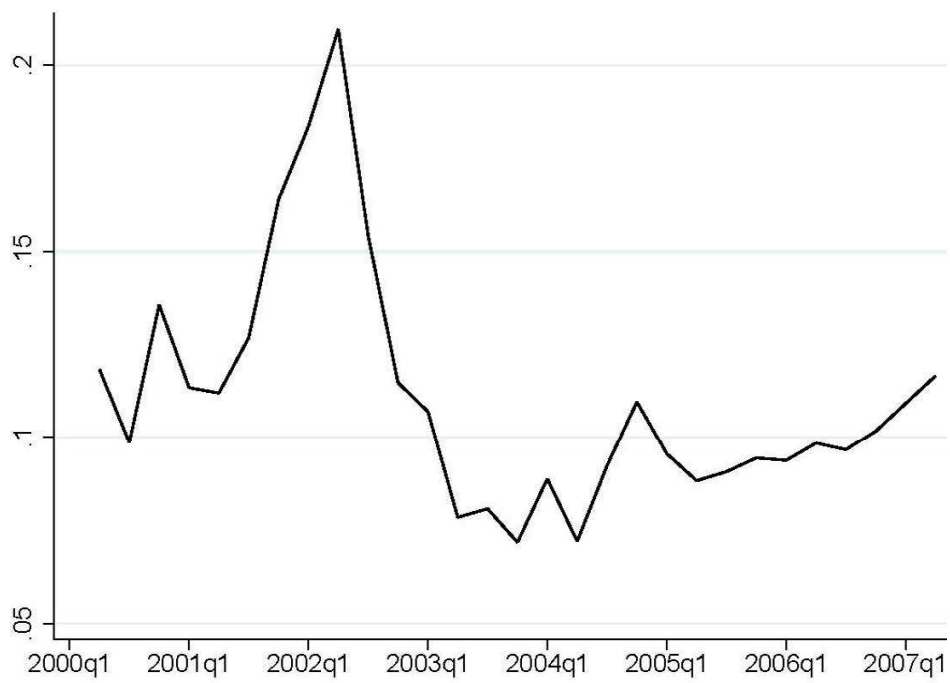


Figure 15: Share of Varieties that are Permanently Dropped by Continuing Firms

	<b>Importer Name</b>	<b>Primary Industry</b>	<b>Primary Sector</b>	<b>Ave. Ann. Imports (\$Millions)</b>	<b>Share of Imports, 2000</b>	<b>Share of Imports, 2002</b>
1	Volkswagen Arg.	Auto Mfg.	Cons. Disc.	544.5	1.6	0.9
2	Ford Arg.	Auto Mfg.	Cons. Disc.	508.2	2.0	2.1
3	General Motors de Arg.	Auto Mfg.	Cons. Disc.	375.7	1.2	2.3
4	Renault Arg.	Auto Mfg.	Cons. Disc.	368.4	2.3	1.0
5	Peugeot Citroen Arg.	Auto Mfg.	Cons. Disc.	308.6	1.5	1.0
6	Daimler Chrysler Arg.	Auto Mfg.	Cons. Disc.	287.3	1.4	0.2
7	Siderar	Steel	Materials	288.8	0.8	1.9
8	Fiat Auto Arg.	Auto Mfg.	Cons. Disc.	242.1	0.6	0.5
9	YPF	Int. Oil & Gas	Energy	236.1	0.4	0.8
10	C.T.I.	Wireless Telecom.	Telecom. Svcs.	210.1	0.2	0.1
11	Telefonica Comm. Per.	Integrated Telecom.	Telecom. Svcs.	189.0	1.2	0.0
12	Monsanto Arg.	Agr. Chems.	Cons. Stpls.	176.5	0.9	2.0
13	Hewlett-Packard Arg.	Tech. Distrib.	IT	172.1	0.9	0.3
14	Toyota Arg.	Auto Mfg.	Cons. Disc.	169.6	0.6	0.7
15	Telecom Personal	Wireless Telecom.	Telecom. Svcs.	165.6	0.8	0.0
16	Petrobras Energia	Int. Oil & Gas	Energy	156.4	0.1	0.5
17	Aluar Aluminio Arg.	Aluminum	Materials	138.4	0.6	1.0
18	Acindar Ind. Arg. de Aceros	Steel	Materials	129.9	0.3	0.9
19	Shell Co. Arg. De Petroleo	Oil & Gas Explo.	Energy	120.6	0.7	1.0
20	Industrias John Deere Arg.	Const & Farm Mach.	Industrials	112.1	0.2	0.2
21	Esso Petrolera Arg.	Oil & Gas Explo.	Energy	103.5	1.1	0.5
22	Siderca	Building Products	Industrials	102.3	0.3	0.6
23	Bayer Arg.	Pharmaceuticals	Healthcare	97.4	0.4	0.8
24	Honda Motor De Arg.	Auto Mfg.	Cons. Disc.	92.4	0.2	0.1
25	BGH	Household Apps.	Cons. Disc.	92.0	0.4	0.2
26	Siemens Arg.	Elect. Equip. & Inst.	IT	91.6	0.6	0.2
27	Scania Arg.	Auto Mfg.	Cons. Disc.	91.5	0.4	0.3
28	Productos Roche	Pharmaceuticals	Healthcare	89.5	0.5	0.8
29	Atanor	Comm. Chems.	Materials	88.9	0.2	0.4
30	Co. de Radiocom. Mobil.	Wireless Telecom.	Telecom. Svcs.	87.2	1.1	0.1
31	IBM Arg.	IT Consulting	IT	83.7	0.5	0.4
32	Syngenta Agro	Agr. Chems.	Materials	82.7	0.1	0.4
33	Alta Plastica	Distributors	Cons. Disc.	76.8	0.4	0.3
34	Iveco Arg.	Auto Mfg.	Cons. Disc.	75.7	0.2	0.1
35	BASF Arg.	Commodity Chems.	Materials	73.9	0.3	0.5
36	Pirelli Neumaticos	Tires & Rubber	Cons. Disc.	73.7	0.2	0.6
37	Minera Alumbreira Limited	Gold	Materials	73.6	0.2	0.8
38	Unilever De Arg.	Household Prods.	Cons. Disc.	72.9	0.3	0.6
39	Tetra Pak	Pkgd. Foods/Meats	Cons. Stpls.	70.7	0.4	0.7
40	Novartis Arg.	Pharmaceuticals	Healthcare	67.5	0.4	0.4
41	Philips Arg.	Tech. Distrib.	IT	66.7	0.3	0.2
42	Procter & Gamble Arg.	Household Prods.	Cons. Disc.	67.6	0.2	0.3
43	Abbott Laboratories Arg.	Pharmaceuticals	Healthcare	65.8	0.4	0.7
44	Voridian Arg.	Commod. Chems.	Materials	65.0	0.2	0.8
45	Bridgestone Firestone Arg.	Auto Parts & Equip.	Cons. Disc.	62.0	0.2	0.4
46	Nidera	Food Distributors	Cons. Stpls.fs	63.2	0.2	0.3
47	AGCO Arg.	Const. & Farm Mach.	Industrials	61.8	0.1	0.1
48	Sipar Aceros	Steel	Materials	60.8	0.1	0.2
49	Aerolineas Arg.	Airlines	Industrials	60.3	0.7	0.2
50	Dow Quimica Arg.	Comm. Chems.	Materials	59.1	0.2	0.4

Table 7: Argentina's 50 Largest Importers