Trade Adjustment and Productivity in Large Crises
Gita Gopinath and Brent Neiman

Abstract:
The authors empirically characterize the mechanics of trade adjustment during the Argentine crisis using detailed firm-level customs data covering the universe of import transactions made during 1996–2008. Their main findings are as follows: First, the extensive margin defined as the entry and exit of firms or of products (at the country level) plays a small role during the crisis. Second, the sub-extensive margin defined as the churning of inputs within firms plays a sizeable role in aggregate adjustment. This implies that the true increase in input costs exceeds that imputed from conventional price indices. Third, the relative importance of these margins and of overall trade adjustment varies with firm size. Motivated by these facts, we build a model of trade in intermediate inputs with heterogeneous firms, fixed import costs, and round-about production to evaluate the channels through which a collapse in imports affects TFP (total factor productivity) in manufacturing. Measured aggregate productivity in the sector depends on within-firm adjustments to the varieties imported as well as the joint distribution of each firm's technology and the share of imports in its total spending on inputs. We simulate an imported input cost shock and show that these mechanisms can deliver quantitatively significant declines in manufacturing TFP.

JEL Classifications: F1, F3

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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 (2010) document a 12 percent decline in manufacturing productivity in Argentina between 2000 and 2002.[1]

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, we develop a model of trade in intermediate inputs with heterogeneous firms, fixed import costs, and round-about production to evaluate the channels through which the collapse in imports affects TFP in manufacturing.

In the trade literature there is extensive analysis, both theoretical and empirical, 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.[2]

We establish the following facts about the Argentine 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. This is also the case for the number of imported product varieties. To elaborate, 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. 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

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[1]Meza and Quintin (2006) document that productivity 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.

[2]Ghironi and Melitz (2005) build a model to highlight the impact of firm entry and exit decisions on business cycle moments.

and also took about five years to recover. However, the net contribution of firm entry and exit explains less than 8 percentage points of the 69 percent decline in imports during the crisis. Product entry and exit explains between 0 and 15 percentage points of the decline depending on the definition used. This finding holds 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 few key firms and sectors. The largest 5 percent of importing firms contribute approximately 85 percent of Argentina's imports and do not change their import status after the crisis.[3] Similarly, the largest 5 percent of imported 6-digit HTS categories together account for about 60 percent of imports. The high concentration in firm and product shares relates to the findings in Bernard, Jensen, and Schott (2009) and the small extensive margin is consistent with the findings in Bernard, Jensen, Redding, and Schott (2009) for U.S. data.[4] Our finding extends their results to a dramatically larger trade adjustment episode using the Argentine experience.

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 at the country level, it may still be the case that several firms stop importing it and thereby experience changes in their own (and therefore aggregate) productivity.

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.[5] These products

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[3]As discussed below, we can rule out the possibility that the largest importers are simply huge distributors or import/export brokers.

[4]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.

[5]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

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 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.

(a) BGH S.A.   (b) Siderca S.A.I.C.
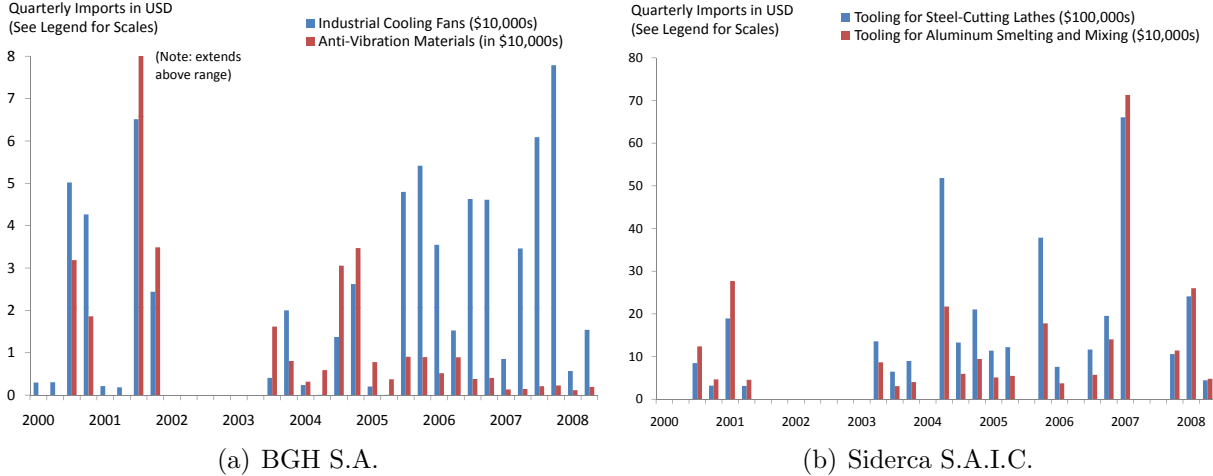
Figure 1: Sample Quarterly Product Imports for Two Large Argentine Firms

This observation leads to our second empirical finding: When we define the extensive margin to include within-firm changes in the mix of imported categories and supplier countries, it begins to play a significant role. 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. As shown in Feenstra (1994), price indices must be adjusted to explicitly account for such changes in varieties. For example, a standard price index that ignores the decline in varieties in Argentina would underestimate the increase in input prices, thereby increasing imputed real intermediate input use and decreasing measured TFP. Calculations from the loss of varieties at the firm level in our data imply that the true imported input price index is 6 to 13 percent higher than the uncorrected price index. These corrections are much larger than what is implied by comparable calculations from aggregate data. In this sense, we emphasize that to evaluate the impact of trade adjustment on productivity, one must

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goods.

think about changes in the *firm-level terms of trade*, rather than the traditional country-level terms of trade.

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, leading to greater average trade adjustment among firms with smaller pre-shock imports. The largest firms adjust primarily by reducing—but not dropping—their imports of particular products, which we call the sub-intensive margin.

It is well understood that changes in import costs can impact firm productivity through altering the number of varieties used when these inputs are imperfectly substitutable Ethier (1982) or because of the difference in quality between domestic and foreign inputs Grossman and Helpman (1991). We incorporate these channels in an environment with heterogeneous firms, monopolistic competition, round-about production, and fixed costs of importing. Each firm's production function combines domestic and imported intermediate inputs that are imperfectly substitutable. We analytically and numerically examine the response of trade, the various extensive and intensive margins of adjustment, and productivity to an increase in the price of imported inputs relative to domestic inputs.

Aggregate productivity in this economy depends on both the exogenous technology of each firm (the ex ante source of heterogeneity) and the share of imported inputs in each firm's total input costs. In the presence of fixed costs, firms with better technology import a larger number of foreign input varieties, as this strategy gives them a cost advantage over the smaller firms. Aggregate TFP is not a function simply of the average technology level nor of the average share of imports in intermediate input spending. Rather, aggregate TFP is determined by the joint distribution of firm-level technologies and import shares.

Shocks that raise the cost of production or lower the level of demand will impact aggregate measured productivity through the following three channels.[6] First, each individual firm will cut back on imports of intermediate inputs, which raises its cost and lowers its productivity. The size of the impact depends on the elasticity of substitution among and between domestic and foreign varieties, expands with the share of intermediate inputs in production, and is

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[6]Such shocks include, among others, negative terms of trade shocks, productivity shocks, or interest rate shocks.

amplified due to round-about production. Second, standard national accounting practices, including those used in Argentina, estimate real imports using a "matched-model" price index which ignores changes in varieties Feenstra (1994). Given the importance of the sub-extensive margin in adjustment, the failure to account for variety adjustment at the firm level impacts measured productivity. Third, changes in firm-level productivity differ across the technology distribution because the magnitude of these first two channels differs based on the amount a firm imports. Therefore, there is also a reallocation of market shares across firms that impacts aggregate TFP measurements.

As a simple illustration, we evaluate the response to a negative terms of trade shock and show in our simulation that these mechanisms can deliver significant declines in manufacturing TFP.[7] When calibrated to match changes in imported input use by the Argentine manufacturing sector during the crisis, our baseline simulation generates a decline in double deflated manufacturing TFP of nearly 3.3 percentage points, about 30 percent of the decline in Argentina's manufacturing TFP as measured in Sandleris and Wright (2010). The simulation also generates movements in the extensive, sub-extensive, and sub-intensive margins, and the relationships between these margins and firm size, consistent with those observed in the Argentine data.

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 evaluates the impact of imported intermediate inputs on productivity. See, for instance, Amiti and Konings (2007) and Goldberg, 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 the sizeable productivity gains from improved access to imports when these imports are imperfectly substitutable for domestic

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[7]We use the phrase "terms of trade" to describe the shock that we consider, but it is more precisely described as a change in the price of imported inputs relative to domestic inputs.

inputs at the firm level. Broda, Greenfield, and Weinstein (2006) evaluate the gains in many countries brought about by increased input varieties at the sector level from 1994–2003.

Next, our work relates to research linking terms of trade shocks to productivity, including during crises. For example, in Mendoza and Yue (2009) the imperfect substitutability between domestic and imported intermediate inputs coupled with a worsening of the terms of trade are crucial to the amplification of financial shocks. In Mendoza (2010) the use of imported intermediates purchased on credit drives the decline in the Solow residual in the model of sudden stops.

Kehoe and Ruhl (2008) argue that (under some assumptions) terms of trade movements have no first-order effect on measured value added when it is measured using the double deflation method. Their result relies on the envelope condition. However, there are two reasons why this result does not hold in our setting. First, in the presence of fixed costs the level of imports is no longer determined by equating the marginal value of an imported input to its price, so the envelope condition no longer holds. Further, when input prices are incorrectly measured because the ideal price index is not used, changes in the number of varieties imported will have a first-order effect on value added. Therefore, changes in the terms of trade will have first-order effects on the level of imports, even when using double deflation.

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.

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 and firm-level Feenstra corrections are needed to evaluate aggregate effects on measured productivity.

Finally, this paper also relates to the literature exemplified by Hsieh and Klenow (2009) and Jones (2010) that examines the impact on aggregate TFP of exogenous distortions that result in resource misallocations across firms, including in environments with round-about production. We propose, empirically document, and endogenize in our model a specific type of channel that acts similarly to these distortions. Sandleris and Wright (2010) and Neumeyer and Sandleris (2010) explore the impact of misallocation on TFP during the Argentine crisis and find that it plays an important role. We view our explanation for TFP 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; 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, and resulted in a 69 percent drop in dollar imports from 2000 to 2002.[8]

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.

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[8]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.

2.1 Detailed Trade Data from Customs

Our data are collected by the customs agency in Argentina, which publicly releases most of the information it collects from import and export shipping manifests. 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.[9] We obtained most of our data from Datamyne, a private provider of trade statistics that receives a daily electronic feed from the customs authorities.[10] 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.

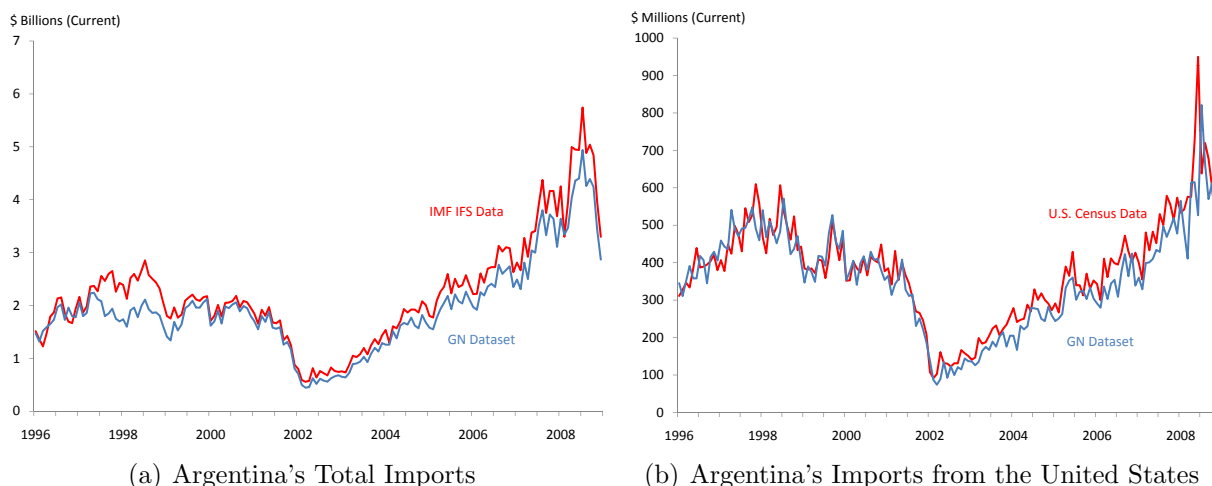(a) Argentina's Total Imports   (b) Argentina's Imports from the United States

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-

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[9]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.

[10]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.

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 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. 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. Finally, since the Nosis database does not contain tax identification codes that we use as our firm identifiers, we hired data analysts to use text-matching software to link the two parts of our export data.[11] 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.[12]

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 includes 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.

In the Appendix, Table 8 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.[13] 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

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[11]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.

[12]See Albornoz, Pardo, Corcos, and Ornelas (2010) for a related analysis of Argentine exports.

[13]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.

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 three main empirical findings.

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 is 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 entry and exit margins 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:

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

where $v_{i,t}$ is firm i's total (fob) spending on imports, Ψ_t is the set of all importing firms 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
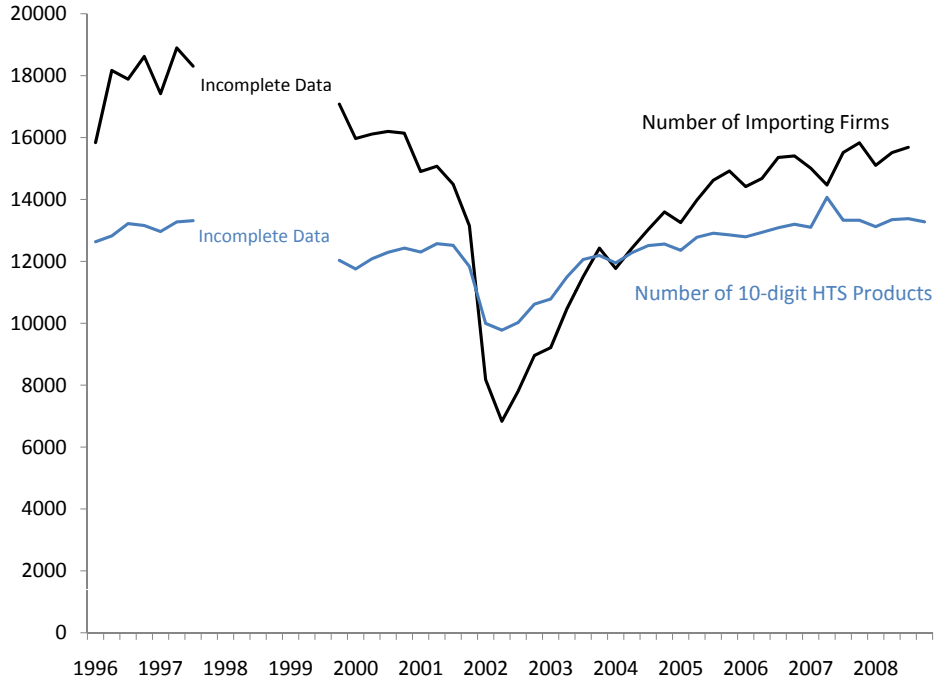
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Figure 3: Number of Importing Firms and Products

in imports from continuing importers. The second term is the extensive margin and captures the volume 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. In aggregate trade flows a small share of changes is attributable to the entry or exit of firms. For example, 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 contribution to the 69 percent decline from the firm extensive margin was less than 8 percentage points.

We can do the equivalent exercise for products, where we use the same disaggregation (1), but redefine Ψ_t to be the set of all imported product categories in period t. Figures 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
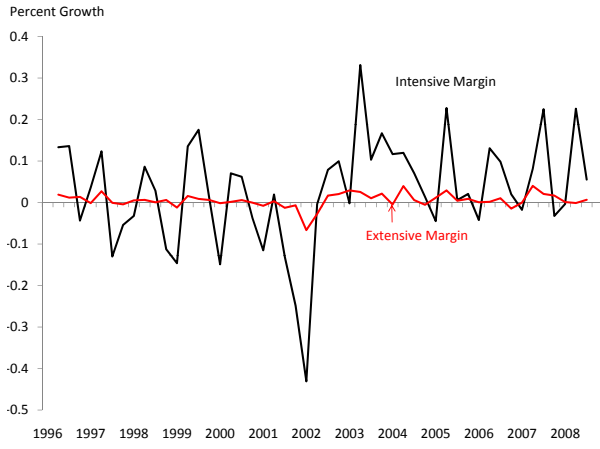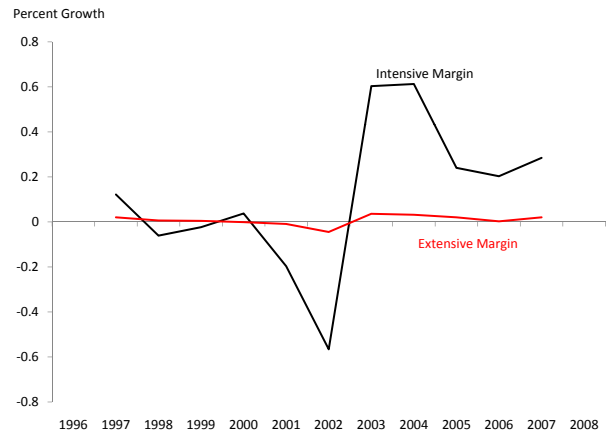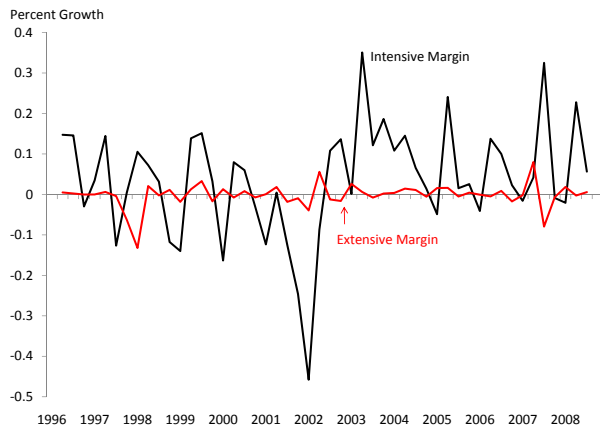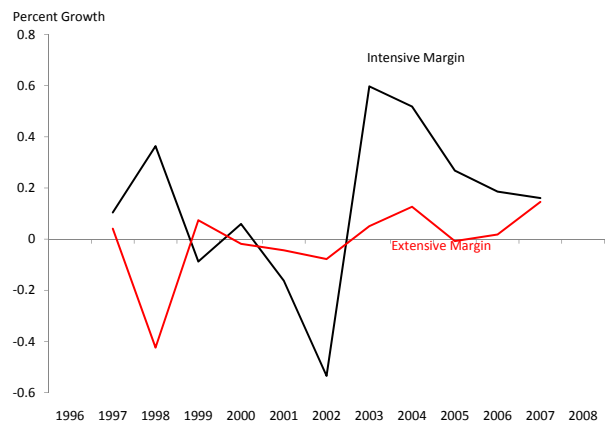
Figure 4: Various Extensive Margin Definitions by Quarterly and Annual Data

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-digits 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 pr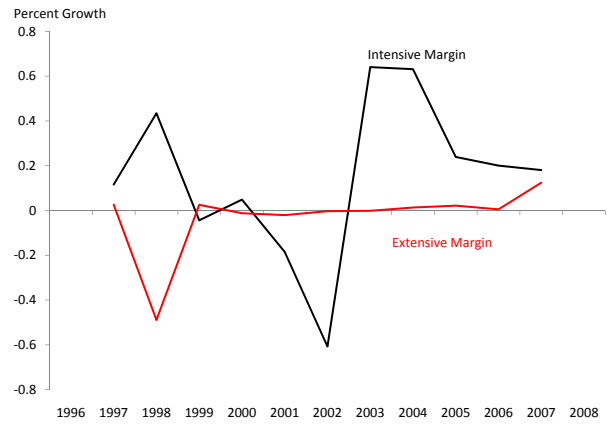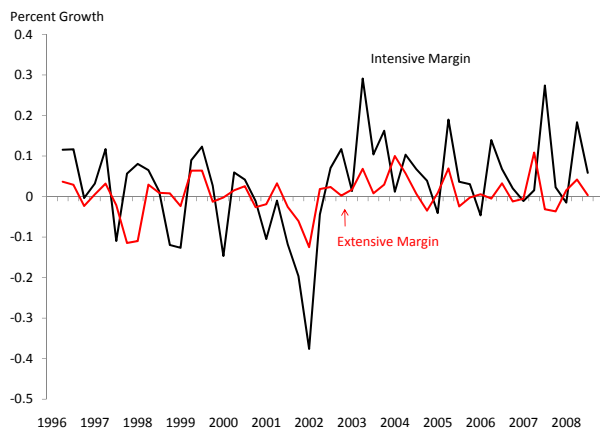oducts is small.[14] (One exception is 1997, when the changing code definitions clearly impacted the 10-digit disaggregation.)

	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. Very little trade adjustment at business-cycle frequencies, even in the event of a large contraction in imports, 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. The true increase in imported input costs exceeds conventional price index measures.

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

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[14]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.

adjustment. This result is depicted in Figure 5, where the sub-extensive margin is defined firm-by-firm and includes changes for continuing importers from newly imported or newly dropped goods (defined, as above, in a variety of ways).[15] We call the change in continuing importer-product combinations the sub-intensive margin.

(a) Importing Firm X HTS10 (Quarterly)

(b) Importing Firm X HTS10 (Annual)

(c) Importing Firm X HTS10 X Country (Quarterly)

(d) Importing Firm X HTS10 X Country (Annual)
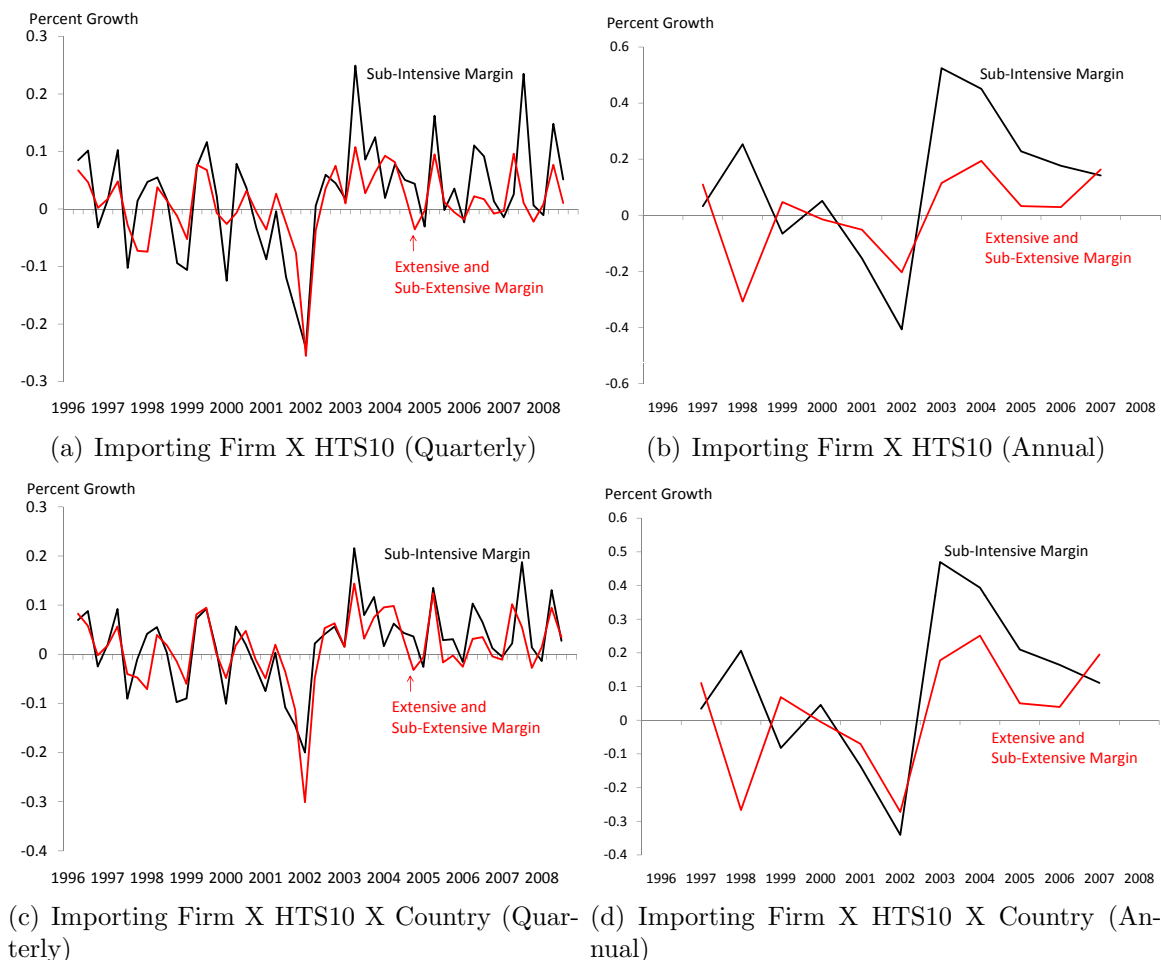
Figure 5: Sub-Extensive Margin

Table 3 quantifies 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 shows 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 sub-extensive margin that captures within-firm changes in import categories explains a large share up to 45 percent

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[15]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).

	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

of the decline, depending on the product definition. Figure 5 shows that the sub-extensive margin can explain more than 50 percent of adjustment at a quarterly frequency.

Finding 2, about the importance of the sub-extensive margin, is consistent with Finding 1, the small role played by the extensive margin, because there is heterogeneity across firms in the products imported. For example, imagine that before the crisis 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 during the four quarters ending in September 2001, before the crisis.[16] 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.

It is clearly the case that as the level of disaggregation increases more of the adjustment will be classified as extensive, so a reasonable question is what is a meaningful level of

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[16]Products in the 25th/50th/75th percentiles had initial annual import volumes of about $30,000/$165,000/$800,000.
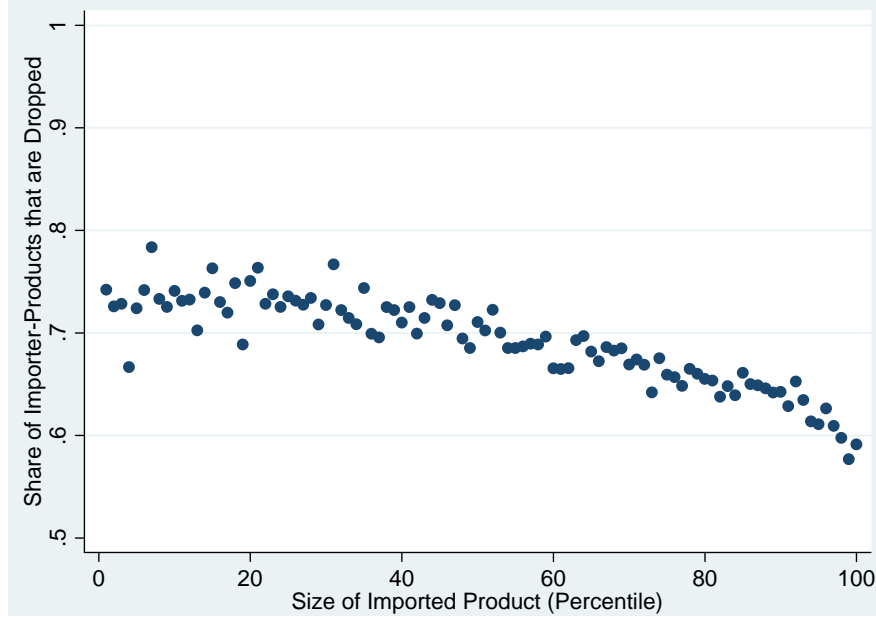
Figure 6: Different Firms Drop Different Products

disaggregation? 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, reasonable assumptions for their purposes. 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. In the context of the above example, the final consumer would be assumed to consume the same number of varieties regardless of whether Siemens and C.T.I. both imported the semiconductor or whether just one of these firms did.

We consider an alternative assumption 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. When varieties of intermediate inputs are imperfect substitutes, the loss of varieties will raise firms' costs of production. As is well known, this cost increase is generally not captured in standard price indices. For example, given a CES production function, the failure to properly

account for dropped inputs can lead to an underestimate of a firm's input cost index and an overestimate of real inputs, which for a given level of output will underestimate TFP. Therefore, one implication of our finding that the sub-extensive margin is more important than the extensive margin is that variety adjustments to price indices should be made with firm-level rather than country-level data.

Feenstra (1994) derived an expression for the degree to which such standard price indices are biased by the failure to account for changing varieties. To get a sense for the quantitative importance of this issue, we compare Feenstra's correction factor when calculated using the extensive margin (country-level) and the sub-extensive margin (firm-level) for various product definitions. 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 $1/(1-\varepsilon)$. The growth of the ideal price index $\widehat{P}_{M_t}$ can be written as:

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

where $v_{k,t}$ is the spending on good k at time t, $\widehat{P}_{\widetilde{M}_t}$ is growth in a standard price index that ignores differences in Ψ_{t-1} and Ψ_t, and $\mathbb{F}_t$ is the correction factor that adjusts for this change in varieties. Hence, $\mathbb{F}$ is the factor by which growth in a conventionally measured price index $\widehat{P}_{\widetilde{M}}$ will differ from growth in the true index $\widehat{P}_M$.

We start by thinking about M as a CES aggregation of all varieties imported into Argentina, regardless of which firm does the importing. The first column of Table 4 lists the aggregate correction factor $\mathbb{F}$ for changes over the period 2000–2002 for various product definitions and for an elasticity equal to 4, a value near the middle of a relatively wide range of estimates found in a large literature.[17] When the extensive margin is defined at the country

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[17]For example, Broda and Weinstein (2006) define a product variety as the interaction of 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) generates an estimate of 8.28, Bernard, Eaton, Kortum, and Jensen (2003) gives an estimate of 3.6, and the estimate in Eaton, Kortum, and Kramarz (2011) equals 4.87.

level, the correction 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, indicating standard price indices would not meaningfully push down measured TFP.

$\varepsilon = 0.75$	$\mathbb{F}$	Weighted Average of $\mathbb{F}_i$		
Percentiles Included:	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: Size of Firm-Level Feenstra Corrections from 2000-2002

If imported inputs are only used by the importing firm, though, this correction factor should be measured at the firm level. Hence, we use a firm-specific correction factor identical to 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 correction 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. The average correction in all columns is significant, ranging from 6.4 to 13.4 percent. Correction factors differ somewhat across specifications, product definitions, and treatment of the outliers, but the general conclusion is that naive input cost estimates (with a CES production function) need to be increased to reflect the loss of input variety, and the scale of this correction when done using aggregated data is far smaller than that which emerges using richer micro data. In essence, rather than the traditional terms of trade, we show that one must focus on the *firm-level terms of trade*.

Mendoza and Yue (2009) suggest that this channel can be at work during sudden stop episodes as firms drop foreign intermediate varieties and thus raise their effective cost of production. However owing to a lack of data, they do not provide evidence of this possible effect. Arkolakis, Demidova, Klenow, and Rodriguez-Clare (2008) 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 imports are concentrated in a few products. They estimate the Feenstra (1994) correction factor to be 0.997 for consumer goods and 1 for intermediate goods.

In the Argentine sudden stop crisis, we similarly find that when changes in varieties are defined at the product and exporting country level, the gains are small. However, when we apply this definition within the firm, the correction factors are much larger and economically important. This is consistent with heterogeneity across firms in the kinds of products imported. While from the economy's perspective there is at least some firm that continues to import a product that was previously imported in significant amounts, each firm finds itself concentrating its purchases in a smaller subset of products during the crisis and dropping products that previously were a significant fraction of their import bundle. This was the case, for instance, for the companies BGH and Siderca which each dropped large categories of imported inputs during the crisis, as shown in Figure 1.

In performing these calculations we have assumed that if a firm does not import a variety it does not have access to it. This clearly need not be the case. The firm can purchase the input it needs from a domestic distributor who imports it or it can draw down holdings of the input in its inventory. 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. However, consistent with Alessandria, Kaboski, and Midrigan (2010), there is evidence that firms consumed inputs out of inventories during the Argentine trade collapse.

To get a quantitative sense for the importance of this mechanism for our measurements, we would ideally like to condition firm import behavior on changes in their inventories. Unfortunately, firm or detailed sector level data on inventories is not broadly available for Argentina. As an alternative, we classify 6-digit HTS sectors based on the inventory/sales ratio in the corresponding 3-digit NAICS manufacturing sector in U.S. Census data from 2000. Figure 7 shows that if we separate sectors into groups with low, medium, and high inventory intensities, we do see differences in the decline in imports.[18] 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.

These results show that ignoring inventories can lead to overstatement of the short-run

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[18]The average monthly inventory to sales ratio in the three groups equals 1.2, 1.5, and 1.9.
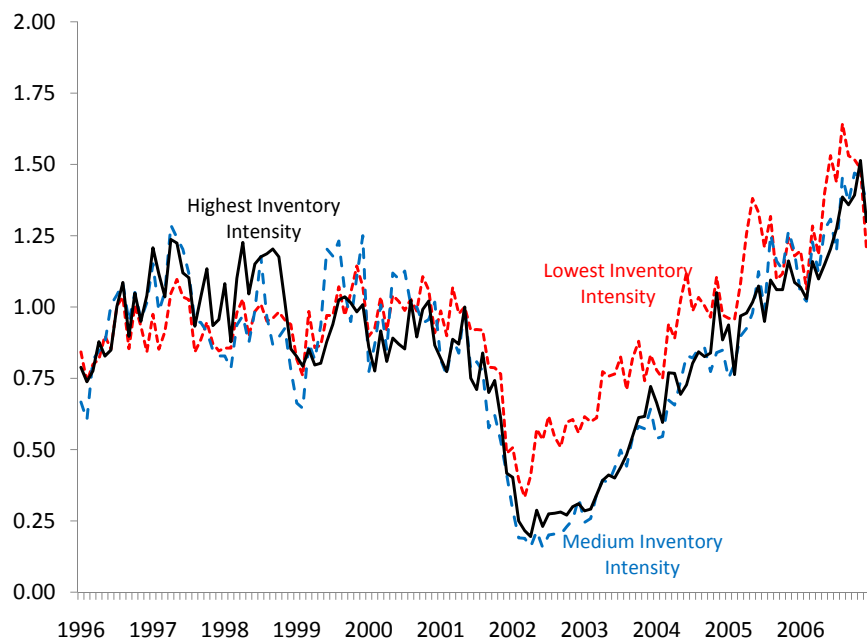
Figure 7: Inventory Intensity and Import Decline

impact of the trade decline on TFP. 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 longer period should alleviate the concern. In our simulations in Section 5, we will also take inventories into account by scaling down the drop in imported input use in production to an amount that would be consistent with aggregate imports behaving like the low inventory intensive goods in Figure 7.

Finally, one might be concerned that the reduction of import varieties need not imply reduced productivity 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 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 in 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 8(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).[19]

(a) Aggregate Import and Export Varieties

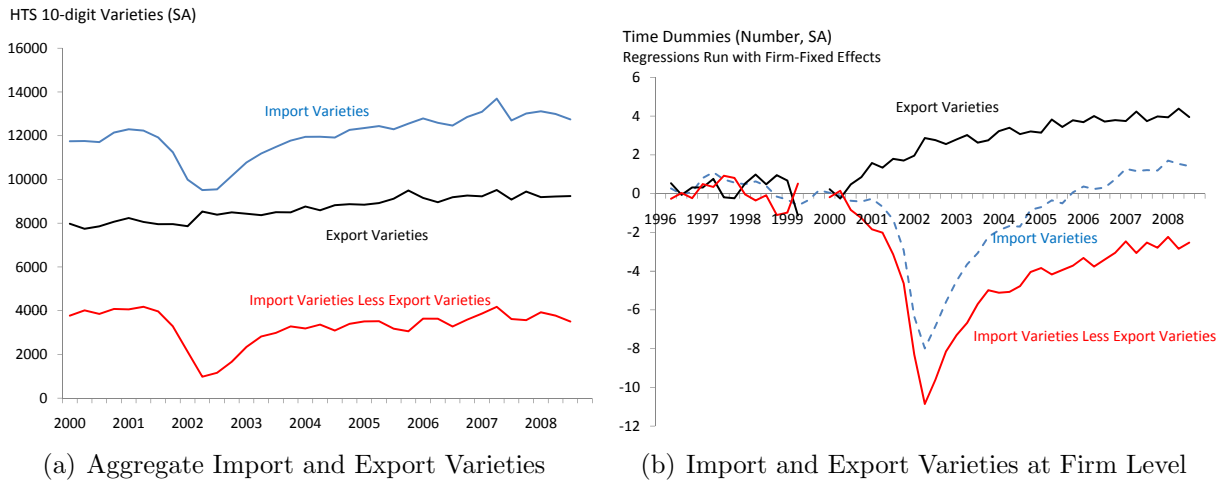(b) Import and Export Varieties at Firm Level

Figure 8: 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 8(b) and show that while the number of both import and export varieties have 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.[20] 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.

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

[19]Plots 8(a) and 8(b) have been seasonally adjusted by removing estimated quarter time-effects.

[20]As discussed in the data description, our economy-wide export data has large gaps before 2000, which is why Figure 8(a) starts in 2000. Our firm-level export data is 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 8(b) will be unaffected. At a minimum, the export series from 2002 onward and the entire import series in Figure 8(b) are uncorrupted by data concerns. Even over this smaller region, the evidence suggests export varieties did not drop along with import varieties.

The pattern of trade adjustment varies with the size of the importer (as proxied by the size of imports). Figure 9(a) divides firms into percentiles based on the size of their imports in 2000.[21] The largest buckets of importers had a smaller magnitude decline in their imports from 2000 to 2002.[22] This pattern holds within small and large importers and is driven by the greater density of smaller firms representing those firms exiting trade.

(a) Size and Import Decline, 2000-2002

(b) Size and Margin of Adjustment, 2000-2002
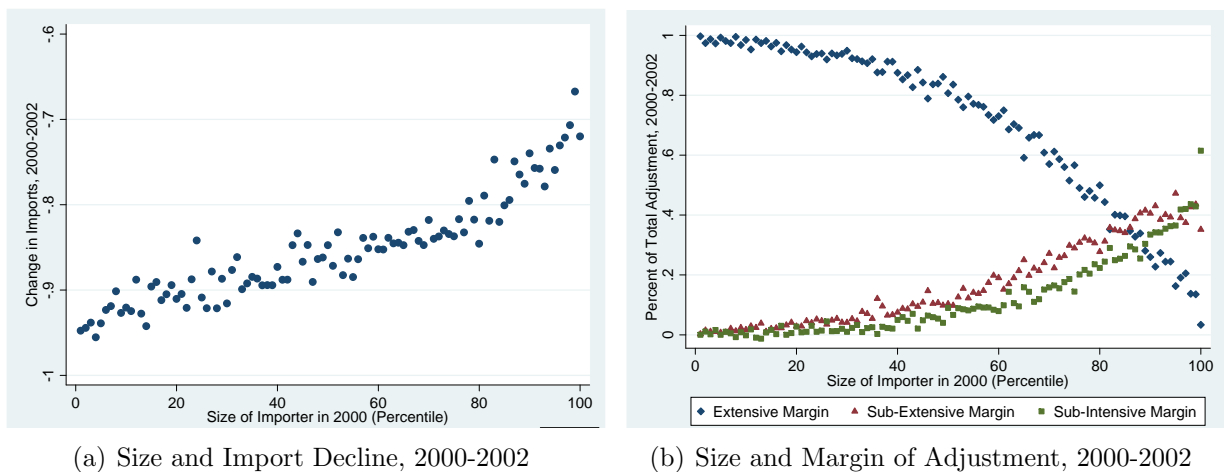
Figure 9: Adjustment by Importer Size, 2000–2002

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 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 9(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).[23] A value along the y-axis equalling 1 for the extensive margin would mean that all importers within that percentile exited trade in 2000. The prevalence of the extensive margin clearly 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

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[21]Firms in the 25th/50th/75th percentiles had initial annual import volumes of about $50,000/$210,000/$770,000.

[22]Figures 9(a) and 9(b) as well as the regressions in this section all omit the very small share of 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.

[23]The plot ignores the small value of firm-product combinations that were added in 2002 relative to 2000.

is greatest among the very largest firms. Heterogeneity in the importance of these margins underlies the heterogeneity in the degree of trade adjustment across firms of different sizes.[24]

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:

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

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.[25] We can only run this regression with the approximately 1,350 firms 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, β_1, is positive and significant at the 1 percent level in all three regressions.[26]

In sum, we show how Argentina's imports contracted rapidly during their sudden stop

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[24]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.

[25]We are motivated by work such as Desai, Foley, and Hines (2004) in considering whether a firm is a 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.

[26]We do note that these regressions are more sensitive to specification than would be suggested by Figure 9(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.

in 2001–2002. Large numbers of firms ceased participation in import markets and many products were no longer imported, but these economy-wide exits were not quantitatively important. The only significant exit margin was from continuing importers dropping some narrowly defined products, even as other firms continued to import those same products. We call this exit margin the sub-extensive margin. Finally, the relative importance of these differing margins and of overall trade adjustment varied across firm size.

One direct implication of these patterns for productivity is that the correction for changing varieties following Feenstra (1994) should be done firm-by-firm rather than for the economy as a whole. An additional implication is that the differential forms of adjustment along the size distribution suggests that there will be a correlation between the reduction in spending on imports and a firm's technology. In the next section we build a model to evaluate the channels through which these features of the data influence measures of manufacturing TFP.

4 Multi-Input Firms, Trade, and Productivity

We present a model of heterogeneous firms that use labor, capital, and multiple intermediate inputs to produce a unique variety of good that is used both for final consumption and as an intermediate input by other firms. Firms use imported as well as domestically sourced intermediate inputs. There are fixed costs to becoming an importer and additional costs that increase with the number of varieties imported.

The intermediate input aggregator of the production function displays a "love of variety" feature with inputs being imperfectly substitutable as in Ethier (1982). In addition, domestic and imported inputs may differ in their productivity à la Grossman and Helpman (1991). In this environment a lack of access to imported inputs will have a negative impact on firm productivity.[27] In the absence of fixed costs, all firms spend the same amount on imported intermediate inputs relative to domestic intermediate inputs. However, in the presence of fixed costs this is no longer the case. Firms with worse technology will not have sufficient

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[27]Halpern, Koren, and Szeidl (2009) present evidence of the importance of both of these features in evaluating the impact of imported intermediate inputs on Hungarian firms.

profits to cover the fixed costs of becoming an importer or of importing a large enough number of varieties. Consequently, firms will differ in their share of spending on imported inputs, which generates an additional source of variation in the unit cost of production across firms besides exogenous differences in technology.

We think of our environment as the manufacturing sector and derive expressions for manufacturing value added and productivity. The change in manufacturing TFP in response to a shock depends on the elasticity of substitution between and within domestic and foreign varieties and is amplified by a factor that depends on the share of intermediate inputs in production and on round-about production. This feature is similar to that in Jones (2010), which evaluates how firm-level distortions are amplified in an environment with intermediate inputs and round-about production. In our environment, these "firm-level distortions" appear endogenously through variations in the unit cost of production across firms due to heterogeneous importing activity. Further, when real imports are estimated by deflating using a "matched-model" price index, as is standard practice in measuring value added, a reduction of import varieties will also lower measured TFP, as discussed in Feenstra (1994). Finally, because firms respond differently to shocks based on their size, we show that manufacturing TFP depends on the joint distribution of (exogenous) firm technology and (endogenous) import shares. This result relates to the work of Hsieh and Klenow (2009) which demonstrates how cross-country differences in the allocation of resources across plants with different technology influences cross-country differences in aggregate TFP. In our environment fixed costs play the role of "frictions."[28]

4.1   Environment

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

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

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

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[28]All proofs in this section are relegated to Appendix A.

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:

$$Z_i = \left[\int_j z_{ij}^\theta dj\right]^{\frac{1}{\theta}}$$

$$M_i = \left[\int_{k \in \Omega_i} (bm_{ik})^\theta dk\right]^{\frac{1}{\theta}}.$$

z_{ij} represents firm i's use of domestically produced inputs j, Ω_i is the set of foreign input varieties imported by i, and m_{ik} is the quantity of imported input k. The parameter $b \geq 1$ captures the quality of imported inputs relative to domestic inputs. 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 round-about nature of production. There are no exports:

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

The final good G is formed by aggregating all the 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.[29]

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[29]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

There are two kinds of per period fixed costs, both denominated in units of labor. One is a fixed entry cost to become an importer and the second is a fixed cost for each variety imported. We assume that the second fixed cost is increasing in the measure of imported varieties, $|\Omega_i|$. 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:

$$F(|\Omega_i|) = \left[f_e I_{|\Omega_i| \neq 0} + f_v \, |\Omega_i|^\lambda \right],$$

where $f_e > 0$, $f_v > 0$, $\lambda > 1$, and $I_{|\Omega_i| \neq 0}$ is an indicator function equalling zero when $|\Omega_i| = 0$ and equalling one otherwise. We denote the labor used to pay fixed costs for firm i as $L_{f,i} = L_i - L_{p,i}$, where L_i is the sum of both types of labor input.

4.2 Firm's Problem

Firms engage in monopolistic competition. Among the decisions they make is whether to become an importer and how many varieties to import, conditional on becoming an importer. Each firm i chooses K_i, $L_{p,i}$, and the set $\{z_{ij}\}$, given the price of labor w, the rental price of capital r, and the set of domestic intermediate input prices $\{p_j\}$. The firms that decide to import additionally choose the set of imported varieties Ω_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.[30],[31] The

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.

[30]We make this simplifying assumption for two reasons. First, the main comparative static we wish to consider is the effect of the Argentine peso devaluation on import purchases. This large common shock likely dominated any idiosyncratic movement in import prices. Second, given the difficulties in measuring quality, we do not attempt to do so in this paper.

[31]In our model all varieties are identical so the specific varieties imported are indeterminate. To make this determinate we can introduce firm-specific quality heterogeneity across import varieties. This extension adds more algebra but the main expressions for aggregate TFP stay qualitatively the same.

firm's unit cost function is then:

$$C_i = \frac{1}{\mu^\mu (1-\mu)^{1-\mu}} \frac{P_V^{1-\mu} P_{X_i}^\mu}{A_i}, \tag{3}$$

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

$$P_{X_i} = \begin{cases} \left(P_Z^{\frac{\rho}{\rho-1}} + P_{M_i}^{\frac{\rho}{\rho-1}} \right)^{\frac{\rho-1}{\rho}} & \text{if firm } i \text{ imports.} \\ P_Z & \text{if firm } i \text{ does not import.} \end{cases}$$

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:

$$\begin{aligned} P_{M_i} &= \left[\int_{k \in \Omega_i} \left(\frac{p_m}{b} \right)^{\frac{\theta}{\theta-1}} dk \right]^{\frac{\theta-1}{\theta}} \\ &= \frac{p_m}{b} |\Omega_i|^{\frac{\theta-1}{\theta}} \end{aligned}$$

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. This arises for two reasons: Foreign inputs are of higher quality when $b > 1$, and the production function exhibits love-of-variety behavior.

Firm i's demand for $L_{p,i}$, K_i, $\{z_{ij}\}$, and $\{m_i\}$ are given by the first-order conditions:

$$wL_{p,i} = (1-\mu)(1-\alpha)C_iY_i \tag{4}$$

$$rK_i = (1-\mu)\alpha C_iY_i \tag{5}$$

$$P_{X_i}X_i = \mu C_iY_i \tag{6}$$

$$z_{ij} = \left(\frac{p_j}{P_Z}\right)^{\frac{1}{\theta-1}}\left(\frac{P_Z}{P_{X_i}}\right)^{\frac{1}{\rho-1}}X_i \quad \text{for each } j,$$

$$m_i = \begin{cases} \left(\frac{p_m}{P_{M_i}}\right)^{\frac{1}{\theta-1}}\left(\frac{P_{M_i}}{bP_{X_i}}\right)^{\frac{1}{\rho-1}}\frac{1}{b}X_i & \text{if firm } i \text{ imports.} \\ 0 & \text{if firm } i \text{ does not import.} \end{cases}$$

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:

$$p_i = \frac{C_i}{\theta}. \tag{7}$$

Firm i then chooses Ω_i to maximize profits net of the cost of importing varieties:

$$\Omega_i = \arg\max_{\Omega_i}\{\Pi_i - wF(|\Omega_i|)\}, \tag{8}$$

where Π_i are profits gross of all fixed costs. As long as the second-order conditions for an interior solution for Ω_i are satisfied it can be shown that firms with better technology will import a larger measure of varieties.[32]

In this environment with fixed costs, the revenue, profits, and value added will be more dispersed than in an environment without fixed costs. This dispersion arises because the higher A_i firms import more varieties and therefore have lower intermediate input unit costs.

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[32]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 λ 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 $[0,1)$.

This cost advantage translates into even lower prices and higher sales, profits, and value added.

4.3 Value Added and Productivity

In this section we evaluate the industry's value added and TFP (the Solow residual measure).[33] In practice the measurement of real value added depends on the method used to deflate nominal value added. The "single deflation" method deflates nominal value added with final output prices. In this case movements in the relative price of inputs to outputs affects value added directly. Alternatively, growth in value added can be measured using the "divisia double deflation" method where both input and output growth are evaluated at constant prices. Obtaining the correct deflators for inputs can be difficult so measured value added may incorporate movements in relative prices even when the goal is to exclude them.[34] We therefore present measures of value added using both single and divisia double deflation approaches. Further, we show how the ideal price deflator will differ from the conventionally measured price index when the number of input varieties changes, as discussed in Section 3 and most famously in Feenstra (1994). Consequently, below we will also evaluate how mismeasurement of the deflator can generate changes in measured TFP.

4.4 Single Deflation Measure of TFP

The single deflation (SD) measure of value added VA is defined as the difference between the value of final goods and the value of imports measured in terms of the price of the final good:

$$VA^{SD} \equiv G - \int_i \frac{P_{M_i} M_i}{P_G} di.$$

Proposition 1 *In the absence of fixed costs, and therefore no extensive margin, single de-*

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[33]See Basu and Fernald (2002) and Fernald and Neiman (2011) for discussions of the difference between aggregate technology and the Solow residual in environments with economic distortions or firm-level heterogeneity.

[34]See Sandleris and Wright (2010), who discuss this for Argentina.

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flated value added in the industry is given by:

$$VA_1^{SD} = (TFP_1) K^\alpha L^{1-\alpha},$$

where

$$TFP_1^{SD} = \left((1-\mu\theta)^{1-\mu}(\mu\theta)^\mu\right)^{\frac{1}{1-\mu}} \gamma^{\frac{\mu}{1-\mu}\frac{\rho-1}{\rho}} Q_\theta^{\frac{1}{1-\mu}}, \tag{9}$$

$$Q_\theta = \left[\int_i A_i^{\frac{\theta}{1-\theta}} di\right]^{\frac{1-\theta}{\theta}},$$

and

$$\gamma = \gamma_i = \frac{P_z Z_i}{P_X X_i}, \qquad K = \int_i K_i di, \qquad L = \int_i L_i di.$$

Single deflated value added at the firm level is given by:

$$VA_{1i}^{SD} \equiv Y_i - \frac{P_{X_i} Xi}{p_i} = (TFP_{1i}) K_i^\alpha L_i^{1-\alpha},$$

where

$$TFP_{1i}^{SD} = \left[(1-\mu\theta)^{1-\mu}\mu\theta^\mu\right]^{\frac{1}{1-\mu}} \gamma^{\frac{\mu}{1-\mu}\frac{\rho-1}{\rho}} \left[A_i s_i^{-\frac{(\theta-1)\mu}{\theta}}\right]^{\frac{1}{1-\mu}}$$

and $s_i = \frac{P_i Y_i}{\int_i P_i Y_i}$. This implies:

$$\frac{TFP_{1i}^{SD}}{TFP_{1j}^{SD}} = \frac{A_i}{A_j}.$$

In the absence of fixed costs, firms' unit costs and TFPs only differ by exogenous technology. All firms import all varieties and the unit cost function across firms differs only to the extent that there are differences in technology. In this environment trade adjustment occurs only through the sub-intensive margin. Note that γ is the share of spending on domestic inputs relative to total spending on inputs, which is identical across firms in the case without fixed costs. Fixing the distribution of firm-level technologies, growth in TFP is simply the growth in the share of domestic inputs relative to total input spending, multiplied by a factor reflecting input intensities and the substitutability of foreign and domestic inputs:

$$\widehat{TFP}_1^{SD} = \widehat{TFP}_{1i}^{SD} = \hat{\gamma}^{\frac{\mu}{1-\mu}\frac{\rho-1}{\rho}},$$

where $\widehat{x} = x'/x$ denotes the gross growth rate of any variable from its initial value x to its subsequent value x'.

This result relates to that in Arkolakis, Costinot, and Rodriguez-Clare (2011), who derive a similar expression for welfare gains from trade adjustment in a broad class of gravity trade models. The expression for value added and TFP^{SD} has the standard effects that follow from a terms of trade shock. The negative effect of a shock that causes the shares of imported inputs to decline and γ_i to increase will be greater the larger the share of imported inputs $(1 - \gamma_i)$, the lower the elasticity of substitution between domestic and foreign inputs, ρ, and the greater the share of intermediate inputs in the production function μ. The fact that imports enter as intermediate inputs and TFP is measured from value added generates the amplifying factor of $1/(1-\mu)$. This is the intermediate input multiplier emphasized by Jones (2010). Next, we consider our environment with fixed costs.

Proposition 2 *In the presence of fixed costs and an extensive margin, single deflated value added in the industry is given by:*

$$VA_2^{SD} = (TFP_2) K^\alpha L_p^{1-\alpha},$$

with $L_p = \int_i L_{p,i} di$ and where

$$TFP_2^{SD} = \left((1 - \mu\theta)^{1-\mu} (\mu\theta)^\mu\right)^{\frac{1}{1-\mu}} \bar{\gamma}^{\frac{\mu}{1-\mu}\frac{\rho-1}{\rho}} Q_{\gamma\theta\rho}^{\frac{1}{1-\mu}}, \tag{10}$$

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

and

$$\bar{\gamma} = \frac{\int_i \gamma_i p_i Y_i di}{\int_i p_i Y_i di}.$$

Single deflated value added at the firm level is given by:

$$VA_{2i}^{SD} = (TFP_{2i}) K_i^\alpha L_{p,i}^{1-\alpha},$$

where

$$TFP_{2i}^{SD} = \left[(1-\mu\theta)^{1-\mu}\mu\theta^{\mu}\right]^{\frac{1}{1-\mu}} \left(A_i\gamma_i^{\frac{(\rho-1)\mu}{\rho}} s_i^{\frac{(\theta-1)\mu}{\theta}}\right)^{\frac{1}{1-\mu}},$$

and $s_i = \frac{P_i Y_i}{\int_i P_i Y_i}$. *This implies:*

$$\frac{TFP_{2i}^{SD}}{TFP_{2j}^{SD}} = \frac{A_i/P_{X_i}^{\mu}}{A_j/P_{X_j}^{\mu}}.$$

Given fixed costs associated with importing, firms adjust via different combinations of the sub-intensive, the sub-extensive, and the extensive margins. Therefore, $\widehat{\gamma}_i$ varies across firms. The growth in TFP in this environment is now:

$$\widehat{TFP}_2^{SD} = \left[\frac{\int_i (\gamma_i')^{\mu\frac{\rho-1}{\rho}\frac{\theta}{1-\theta}} A_i^{\frac{\theta}{1-\theta}} di}{\int_i \gamma_i^{\mu\frac{\rho-1}{\rho}\frac{\theta}{1-\theta}} A_i^{\frac{\theta}{1-\theta}} di}\right]^{\frac{1}{1-\mu}\frac{1-\theta}{\theta}}.$$

The labor used in fixed costs, $L_f = L - L_p$, may be included in TFP calculations. The reduction of import varieties increases the price index, as reflected in $\widehat{TFP}_2$, but has the benefit of reducing labor allocated to fixed costs. We consider this explicitly later.

Firm-level TFP measurements will depend on relative technology as well as the relative input cost of the intermediate input bundle. With fixed costs of importing, the share of input spending on imports, $(1 - \gamma_i)$, is no longer the same across firms. Firms with better technology (higher A) will import more, have a lower input price index P_{X_i}, and therefore have even higher measured productivity. Industry-level TFP, depicted in Equation (10), now depends on an aggregation of the individual exogenous technologies scaled by the share of input spending on domestic inputs. The only instance when the two expressions for TFP — Equation (9) and Equation (10) — are the same is when $\gamma_i = \gamma$, which will be the case if fixed costs are so high that they prohibit all firms from importing or if fixed costs are so low that all firms always import the same set of goods. The most productive firms will have the lowest γ_i and the industry-level TFP calculation will put an even greater weight on these firms as long as θ and ρ lie between 0 and 1.[35] In the spirit of Hsieh and Klenow (2009), there is an additional impact on sector-level TFP relative to the case without fixed costs that comes from the reallocation of market shares.

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[35] As shown earlier, as long as λ is sufficiently high firms with better technologies will have higher Ω_i and therefore lower P_{M_i}. Since P_z is the same across all firms it follows that higher productivity firms have lower γ_i.

4.5 Divisia Double Deflation Measure of TFP

We now evaluate how the expressions for value added and TFP are affected in the case of divisia double deflation (DD), when prices are held fixed at a baseline value. Kehoe and Ruhl (2008) argue that under certain assumptions, terms of trade movements have no first-order effect on value added and TFP when they are measured using the double deflation procedure because all inputs and outputs are measured at constant base period prices. The only effect that remains is the indirect effect from changes in the quantity of imports resulting from this price movement. Given that the initial level of imports in this environment is at the optimal level, changes in the terms of trade will produce only second- and higher-order effects on value added or on GDP (the envelope condition).

This result does not hold in our setting for two reasons. First, with fixed costs for purchasing each import variety, the level of imports is no longer determined by equating the marginal value of inputs to their price. Therefore, changes in the terms of trade will have first-order effects on the level of imports, even when using the double deflation method. Second, when input prices are incorrectly measured because the ideal price index is not used, terms-of-trade induced changes in the number of varieties imported will have a first-order effect on double deflated TFP. Lastly, we note that the large scale of the terms of trade shocks in crises such as Argentina's suggests second- and higher-order terms may in fact be quantitatively meaningful.

Firm-level growth in divisia double deflated value added is defined as:

$$\ln \widehat{VA}_{i,t+1}^{DD} = \frac{\ln \widehat{Y}_{i,t+1} - s_{X_i} \ln \widehat{X}_{i,t+1}}{1 - s_{X_i}},$$

where $s_{X_i} = (P_{X_i} X_i) / (P_{Y_i} Y_i) = \mu \theta$. In the case when X_i is measured correctly — that is, by deflating nominal spending on intermediates by the ideal (variety-adjusted) price index P_{X_i} — we obtain the following relation between growth in firm value added using the single and double deflation methods:

$$\ln \widehat{VA}_{i,t+1}^{DD} = \ln \widehat{VA}_{i,t+1}^{SD} - \frac{\mu \theta}{1 - \mu \theta} \ln \left(\frac{\widehat{p}_{i,t+1}}{\widehat{P}_{X_i,t+1}} \right).$$

The magnitude of growth in double deflated value added and TFP in response to terms of trade shocks is lower than that using the single deflation method due to the term $\ln\left(\widehat{p}_{i,t+1}/\widehat{P}_{X_i,t+1}\right)$.

In the case when X_i is measured incorrectly — that is, by deflating nominal spending on intermediates by a conventional price index that ignores changes in the number of varieties — firm-level growth in double deflated value added (denoted with superscript $\widetilde{DD}$) can be written as:

$$\ln\widehat{VA}_{i,t+1}^{\widetilde{DD}} = \frac{\ln\widehat{Y}_{i,t+1} - \mu\theta\ln\left(\tilde{X}_{i,t+1}/\tilde{X}_{i,t}\right)}{1 - \mu\theta},$$

where

$$\tilde{X}_i = \frac{P_{X_i}X_i}{P_{\tilde{X}_i}},$$

$$P_{\tilde{X}_i} = \left[P_Z^{\frac{\rho}{\rho-1}} + P_{\tilde{M}_i}^{\frac{\rho}{\rho-1}}\right]^{\frac{\rho-1}{\rho}},$$

and

$$P_{\tilde{M}_i} = p_m = P_{M_i}b\left|\Omega_i\right|^{\frac{1-\theta}{\theta}}.$$

Note that the firm-level Feenstra correction (2) in this environment is $\mathbb{F}_{i,t} = \widehat{\left|\Omega_{i,t}\right|}^{\frac{\theta-1}{\theta}}$.[36]

We can therefore relate double deflated value added growth measured with conventional price indices to the ideal index double deflated value added growth and a function of the Feenstra correction term for changing import varieties:

$$\ln\widehat{VA}_{i,t+1}^{\widetilde{DD}} = \ln\widehat{VA}_{i,t+1}^{DD} - \frac{\mu\theta}{1-\mu\theta}\ln\left(\frac{\widehat{P}_{X_i,t+1}}{\widehat{P}_{\tilde{X}_i,t+1}}\right),$$

where $\left(\frac{\widehat{P}_{X_i,t+1}}{\widehat{P}_{\tilde{X}_i,t+1}}\right)$ is an increasing function of $\mathbb{F}_i$.[37] As discussed in Section 3, a shock that causes a decline in the number of varieties imported will imply $\mathbb{F}_i > 1$, all else equal, and consequently an even larger decline in measured productivity as compared to the correctly measured double deflated change in value added.

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[36]To avoid additional notation, we assume the quality parameter b is fixed. Unobserved changes in b, however, would clearly also show up in the Feenstra correction term.

[37]It can be shown that: $\frac{\widehat{P}_{X_i,t+1}}{\widehat{P}_{\tilde{X}_i,t+1}} = \left(\frac{\mathbb{F}_{i,t+1}^{\frac{\rho}{1-\rho}}\zeta_{i,t}}{1-\widehat{\gamma}_{i,t+1}} + \frac{1-\zeta_{i,t}}{\widehat{\gamma}_{i,t+1}}\right)^{\frac{1-\rho}{\rho}} = \left(\frac{\left|\widehat{\Omega}_{i,t+1}\right|^{\frac{\theta-1}{\theta}\frac{\rho}{1-\rho}}\zeta_{i,t}}{1-\widehat{\gamma}_{i,t+1}} + \frac{1-\zeta_{i,t}}{\widehat{\gamma}_{i,t+1}}\right)^{\frac{1-\rho}{\rho}}$, where $\zeta_{i,t} = \left(1 + \frac{1-\gamma_{i,t}}{\gamma_{i,t}}b^{\frac{\rho}{1-\rho}}\left|\Omega_{i,t}\right|^{\frac{1-\theta}{\theta}\frac{\rho}{1-\rho}}\right)$.

Growth in sectoral value added using ideal price indices is obtained as a weighted average of growth rates of firm value added:

$$\ln \widehat{VA}_{t+1}^{DD} = \int_i \omega_i \ln \widehat{VA}_{i,t+1}^{DD} di,$$

and the equivalent expression when conventional deflators are used, where ω_i is the share of nominal value added by firm i in total nominal value added. By using this sector-level value added we can then calculate TFP as the Solow residual.

4.6   Round-about Production

In this sub-section we clarify the role that round-about production plays. Suppose we shut down the round-about nature of production. That is:

$$X_i = \left[\overline{Z}_i^\rho + M_i^\rho \right]^{\frac{1}{\rho}},$$

and

$$Y_i = g_i,$$

where $\overline{Z}_i$ represents purchases of domestic intermediate inputs from outside the industry we evaluate. Now, both the domestic and imported input prices are exogenous to the firm and all of the firm's output goes into final consumption. Under this assumption the industry's single deflated real value added is given by:

$$
\begin{aligned}
VA^{NRA} &= G - \frac{\int_i P_{X_i} X_i di}{P_G} \\
&= K^{1-\alpha} L_p^\alpha \overline{\gamma}^{\frac{\mu}{1-\mu}\frac{\rho-1}{\rho}} Q_{\gamma\theta\rho}^{\frac{1}{1-\mu}} P_I^{\frac{\mu}{1-\mu}},
\end{aligned}
$$

where $P_I \equiv P_G/P_{\overline{Z}}$ is the ratio of the industry's output price relative to the price of its domestic intermediate inputs. This expression is identical to Equation (10) except for the relative price term $P_I^{\frac{\mu}{1-\mu}}$, which equals 1 in the case of round-about production. Crucially, though, the γ_i's and $\overline{\gamma}$'s can be very different in the two environments.

With roundabout production, any cost shock (like an increase in the price of imports)

that raises the industry's output price will also raise the industry's input price. Without round-about production, this need not happen and, as a result, $\widehat{P}_I > 1$. Hence, all else equal and for the same change in the γ_i's, the impact on value added and TFP will be lower in the case without round-about production.

In sum, the impact on aggregate TFP of cost or demand shocks will depend on the response of the individual γ_i's and of the sub-extensive margin (Ω) to the shock. If one has information on these variables pre- and post-crisis then one can estimate the impact on TFP, given estimates of the relevant elasticity parameters, regardless of the source of the shock.

In the absence of firm level data on γ_i we instead evaluate the economy's response to a terms of trade shocks by calibrating the model to the data as best possible. The impact on manufacturing TFP will depend on whether value added is measured using single deflation, divisia double deflation with ideal price indices, or divisia double deflation with conventional price indices. In our simulation below, we will use all three methods to calculate TFP.

5   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 ω. 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, Equations (7) and (8), are satisfied, given final demand in the economy.

5.1   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 $|\Omega_i^1|$, which may be zero.[38] 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 round-about production. In particular, we iterate the system:

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

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

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.

5.2 Calibration

We now describe our calibrations of the most important parameters used in our baseline simulation, though we later report results for a wide range of 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.[39] The first column of 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.

We can directly measure the share of input spending on domestic goods, γ, for 1997 from the input-output table, but Argentina has not released a version for subsequent years. The

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[38]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 baseline calibration has a market share of only 5 percent.

[39]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.

θ	ρ	b	μ	α	λ	f_e	f_v	η
0.75	0.75	1	2/3	1/3	2	0.125	0.0075	0.8

w	r	C	P_N	ω	p_m^{pre}	$\widehat{p}_m$	γ^{pre}	γ^{post}
50	50	$1x10^8$	1	0.2	1.74	1.155	0.83	0.89

Table 5: Baseline Simulation Parameters

annual manufacturing census gives annual input spending by manufacturers, though, so we can approximate γ in future years by assuming that the growth in manufacturing spending on imported inputs follows the growth in total imports.[40] This results in a pre-crisis minimum value of 0.83 for γ. We choose the distribution of technologies A_i such that the distribution of import shares lines up well with what was observed in the data. 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.
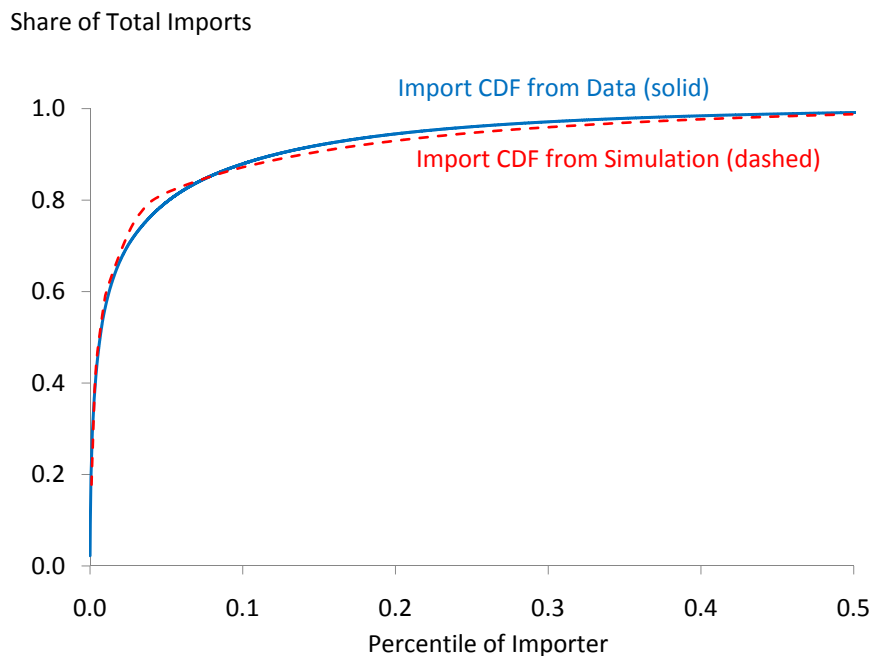
Figure 10: Concentration of Imports in the Data (2000) and in the Simulation

We shock p_m such that, given the values for P_N, ω, and η, the share of manufacturing input spending allocated to imported goods, $1 - \gamma$, decreases to 0.11, consistent with the

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[40]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.

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, ω, and η are not important for our simulation other than their determination of the real decline in manufacturing value added.[41] Given these values and the shock to p_m, the implied reduction in manufacturing value added equals 13 percent, in line with the 12 percent decline during the crisis in the industrial production index, obtained from Global Financial Data.[42]

5.3   Simulated Adjustment Patterns

We now present results from our simulation aimed at demonstrating that the model can reproduce the three empirical findings discussed in Section 3. Our first empirical finding is that after the crisis began the extensive margin in Argentina was large in the sense that many previous importers stopped importing, but this finding is unimportant in the sense that the sum of those flows explain a small share of Argentina's total trade adjustment. Table 6 shows, consistent with the empirical finding, that a large share of very small importers exit trade in our simulated data. Row (1) shows that nearly one-third of all simulated firms that imported before the increase in p_m ceased to do so afterwards. However, as shown in row (2a), the total contribution of these flows to the total decline in imports is only about 1 percent.

Our second empirical finding is that the sub-extensive margin is as comparably important for trade adjustment as is the sub-intensive margin. Further, we calculate that the average import-share weighted average of firm-level Feenstra corrections for the degree to which standard price indices would underestimate the increase in the ideal price index due to dropped varieties equalled 6 to 13 percent. Row (2b) of Table 6 shows that the sub-extensive margin in our baseline simulation explains 47 percent of the total import decline; this result is in line with the data using the most disaggregated product definition. The implied import-share weighted average of firm-level Feenstra corrections is shown in row (3) and equals 8.3 percent, near the middle of the range calculated in the data.

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[41]For example, exogenously imposing a change in aggregate final consumption C or changing the parameter η would be isomorphic for the objects in the manufacturing sector we focus on.

[42]The Argentine national accounts lists a decline of 17 percent over this same period.

		Baseline Simulation	Data
(1)	% of Firms Exiting	0.30	≈ 0.50
	Share of Adjustment Due to:		
(2a)	Extensive Margin	0.01	0.11
(2b)	Sub-Extensive Margin	0.47	0.45
(2c)	Sub-Intensive Margin	0.52	0.44
(3)	Weighted-Average Firm-Level Feenstra Correction	1.083	1.064 to 1.134
(4)	$ln(\widehat{\widehat{TFP}}^{SD})$	-0.049	
(5)	$ln(\widehat{\widehat{TFP}}^{DD})$	-0.025	
(6)	$ln(\widehat{\widehat{TFP}}^{\widetilde{DD}})$	-0.049	
(7)	$ln(\widehat{\widehat{TFP}}^{\widetilde{DD}})$ including L_f	-0.033	

Table 6: Baseline Simulation Results

(a) Scale of Trade Adjustment and Size
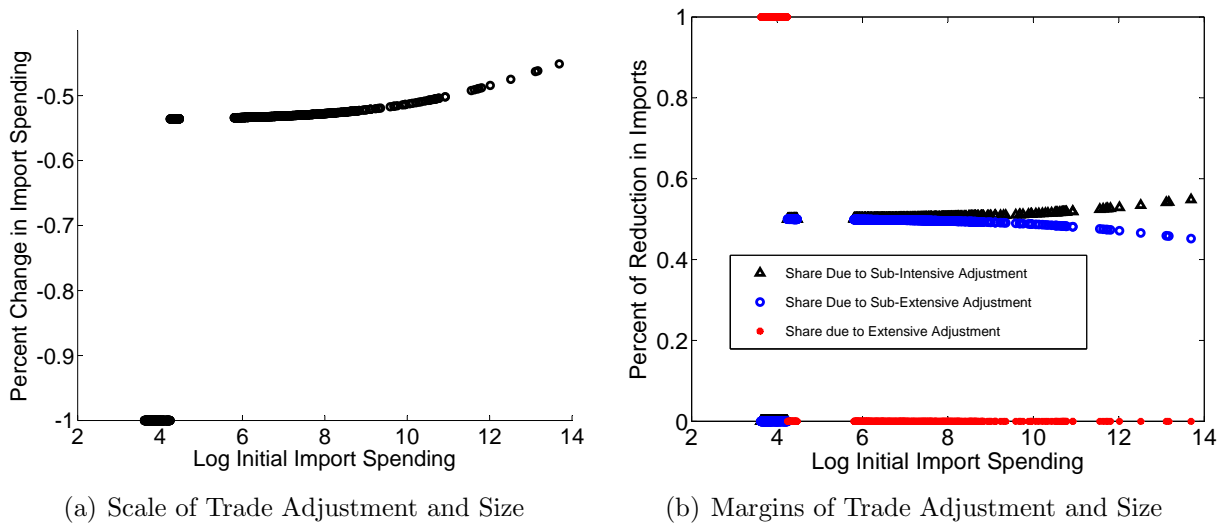
(b) Margins of Trade Adjustment and Size

Figure 11: Adjustment and Size in Simulation

Finally, our third empirical finding demonstrates 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. In the data this result is driven by the by reduced prevalence of extensive margin adjusters among larger firms. Figure 11 plots trade adjustment and importer size from our simulated data. Only the smallest firms adjusted along the extensive margin, but the difference in scale between extensive margin adjusters and other firms is large enough where one could see how, with some randomness (such as technology shocks) introduced to this environment, this effect would generate the clear relationship between firm size and import trade adjustment as seen in Figure 9.

Though the difference in adjustment among continuing importers is mild, Figure 11(a) shows that larger firms in the simulation adjust slightly 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.[43] In our environment the size-elasticity relation depends on whether $\left(\frac{\rho}{1-\rho} - \frac{\theta\mu}{1-\theta}\right)$ is positive or negative as discussed in Appendix B. Firms with worse technology (lower size) have a higher γ_i. A higher γ_i on one hand increases the responsiveness to a shock of the number of foreign varieties imported (because the firm with a higher γ_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:

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

This first effect dominates in our baseline simulation given our choice of parameter values.

5.4   Simulated Baseline Declines in Manufacturing TFP

Figure 12 shows how these changes translate into $(\widehat{\gamma_i} - 1)$ and $ln(\widehat{\widetilde{TFP}}_i^{\widetilde{DD}})$ across the size distribution of firms. The firms with the best technology import the most and are at the

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[43]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.

right of the plot. Their initial γ_i values were lowest and the percent increase in those values is greatest.[44] This results in the largest decline for those firms in both single and double deflated TFP.
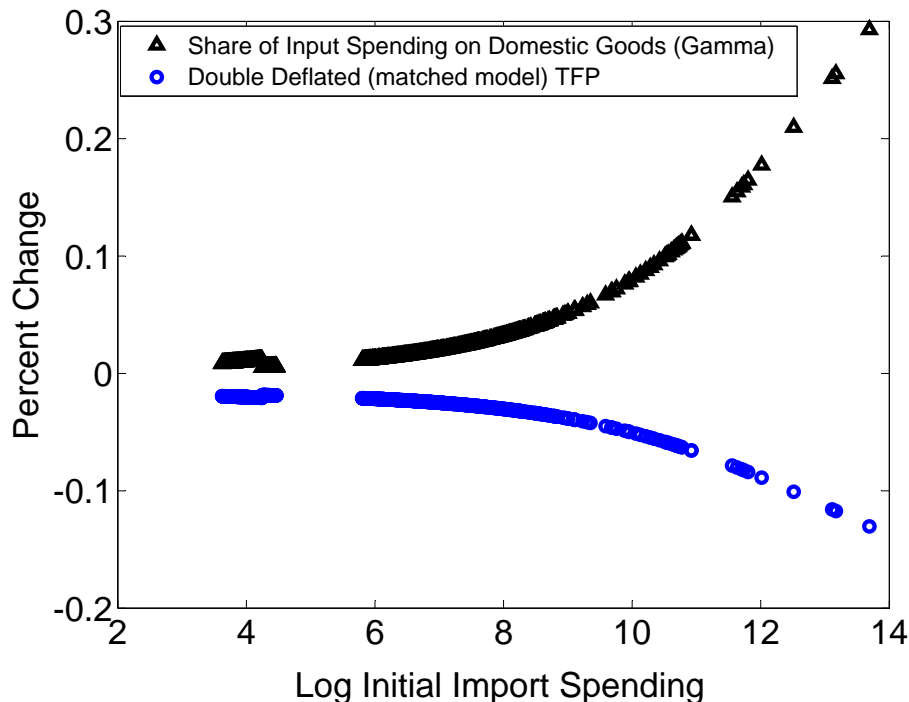

Figure 12: Changes in Domestic Input Share and TFP

We next aggregate across firms and consider overall manufacturing TFP. Row (4) of Table 6 shows that the percentage change in single deflated manufacturing TFP, corresponding to Equation (10), is -4.9 percent. This is a bit more than 40 percent of the total measured decline in Argentine manufacturing TFP documented in Sandleris and Wright (2010).

A calculation only using information on the aggregate change in γ as in Equation (9) produces a comparable measurement for the change in TFP of -4.6 percent. One might be tempted to interpret this result as suggesting that the firm-level structure is less important in determining how TFP changes in this economy. But the industry's firm-level structure in

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[44]The percentage change in γ_i in response to an increase in p_m depends on two terms as given by equation (13) in Appendix B. First, for a given change in the relative price P_{Mi}/P_z, the lower the γ_i the higher the percentage change in γ_i. This is the direct effect. The second term depends on how the optimal relative price P_{Mi}/P_z varies with γ_i. This in turn depends on the percent change in Ω_i as a function of γ_i. Under our parameter assumptions, the largest firms have the smallest decline in Ω_i. However, the direct effect of the lower initial γ_i dominates, which is why the net effect is for the low γ_i firms (the largest firms) to have the biggest decline in their γ.

fact determines how the aggregate trade shares move in response to a given shock. Further, for double deflated GDP measurements, the firm-level Feenstra correction — unobservable in aggregate data — is the most important determinant of the decline in TFP.

We now consider measurements of changes in divisia double deflated TFP in our environment.[45] Row (5) of Table 6 gives the decline in TFP calculated using the proper, variety-adjusted, ideal price index for imports. Consistent with the analysis in Section 3, this is smaller than the single deflated TFP decline because it omits the direct effect of the relative price movement between inputs and outputs.

The method of calculation we believe to be most representative of the methods actually used in national product accounting, including in Argentina, is double deflation but with a matched-model price index (uncorrected for variety changes) used as the deflator. Using this method, Row (6) reports that we find a 4.9 percent decline in TFP, which by coincidence happens to equal the value using the single deflation method. Based on this number, we conclude that the mechanisms highlighted in our model can generate first-order declines in TFP in episodes of rapid trade adjustment.

Finally, as mentioned earlier, we note that as firms drop varieties, they save on the labor previously used to pay the importing fixed costs. This force acts counter to the mechanisms described above that push down TFP and may to some extent dampen the decline. We show in row (7) of Table 6 that if we also account for this reduction of labor input by pooling the labor used for operations with that used for fixed costs into our Solow residual calculation, we reduce the magnitude of the TFP decline to 3.3 percent.

5.5 Robustness

In this sub-section, we re-simulate our system with a number of different assumptions to determine the sensitivity of the mechanisms we focus on that impact measured TFP adjustment. Row (1) of Table 7 reproduces our baseline simulation figures for the divisia double

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[45]In the single-deflation case, we compare a fixed-weight average of firm-level Solow residuals with a calculation using aggregate value added and factor inputs. The difference is only about 0.1 percentage point and is driven by re-allocating the market shares across firms. Given that this result is small, we follow the equations from Section 4 and measure the double-deflated TFP changes firm by firm and aggregate up using shares in nominal output.

deflated TFP, using a matched-model price index, for the standard case as well as the one adding the labor used in paying fixed importing costs. We next aim to evaluate the impact of the same shock by taking into account the possibility that firms might not reduce their use of imported inputs as much as they reduce their imports of these inputs because they can draw down on inventories.

		$ln(\widehat{\widetilde{TFP}}^{\widetilde{DD}})$	$ln(\widehat{\widetilde{TFP}}^{\widetilde{DD}})$ including L_f
(1)	Baseline	-0.049	-0.033
(2)	Inventories	-0.025	-0.017
(3)	No Round-About Production	-0.030	-0.016
(4)	$\rho = 0.50$	-0.128	-0.109
(5)	$\theta = 0.90$	-0.027	-0.023
(6)	$\rho = 0.50, \theta = 0.90$	-0.055	-0.049

Table 7: Alternative Simulation Results

As shown in Figure 7, 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, γ, under the assumption that aggregate import growth is scaled down to match the experience of these least inventory-intensive sectors, we obtain a post-crisis value for γ of 0.86 rather than the baseline post-crisis value of 0.89. Therefore, row (2) of Table 7 reports TFP declines in simulations where growth in the input price is limited such that the movement in γ is reduced accordingly. The TFP declines (with and without accounting for re-gained labor) are reduced, though remain economically significant.

Next, for this economy, we consider the impact of eliminating round-about production by specifying that the price of domestic inputs P_Z is fixed at its initial value from the baseline simulation and is completely insensitive to changes in the import price p_m. We set $\widehat{p}_m$ to match the movement in γ from the baseline simulation. As expected, this also reduces the declines in manufacturing TFP, though these again remain economically significant.

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Finally, we consider varying values for the key elasticity parameters ρ and θ. We adjust the initial import price p_m to match the initial aggregate import share and continue to adjust $\widehat{p}_m$ in order to match the baseline movement in γ over the crisis. 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. This produces large TFP declines, shown in row (4), exceeding 10 percent even after taking account of fixed cost labor savings.[46] Row (5) shows TFP declines between 2 and 3 percent for the scenario where we increase θ to 0.90, corresponding to an 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 TFP declines near 5.5 percent, excluding saved fixed cost labor, and near 4.9 percent when including it in the calculation.

In sum, our simulations confirm that the mechanisms motivated in the empirical analyses of Section 3 and analyzed in the model of Section 4 are likely of first-order quantitative significance to declines in manufacturing TFP witnessed in large crises and current account reversals. This result holds for single deflated TFP and divisia double deflated TFP. The magnitude of the effect remains significant even after taking account of inventories, eliminating round-about production linkages, and accounting for the reduction in labor input that follows a reduction in imported varieties. For a given change in import shares, the magnitude of the TFP decline increases as home and foreign inputs become less substitutable.

6   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. We find that the extensive margin of trade, where previous importers stop importing, is not quantitatively significant. However, the within-firm churning of inputs that we call the sub-

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[46]We note that as we allow ρ to decline toward zero, the magnitudes of estimated TFP declines continue to grow and can easily reach 15 or 20 percent.

extensive margin is quantitatively important. Finally, the scale and type of trade adjustment differs with the size of the importer. Motivated by these empirical findings, we build a heterogeneous firm model with round-about production and fixed costs of importing. The model replicates the above empirical findings and, across multiple methods of calculating TFP, generates economically significant declines in measured productivity.

Argentina's GDP started recovering by 2003 and this was accompanied by a 9 percent improvement in its terms of trade from 2002 to 2003 (and an additional 6 percent by 2006) and a recovery in imports. Our mechanism therefore might also help explain the rebound in TFP.

Crises such as the one Argentina experienced surely involve multiple shocks, and no one channel can explain all of the decline in TFP. Our simulations suggest, however, that the reduced use of imported intermediate inputs is a significant contributor to the manufacturing productivity losses experienced during crises.

References

Albornoz-Crespo, Facundo, Hector F. Calvo Pardo, Gregory Corcos, and Emanuel Ornelas. 2010. "Sequential Exporting." Discussion Paper No. 8103. London: Centre for Economic Policy Research. Available at **www.cepr.org/pubs/dps/DP8103.asp.**

Alessandria, George, Joseph P. Kaboski, and Virgiliu Midrigan. 2010. "Inventories, Lumpy Trade, and Large Devaluations." *American Economic Review* 100(5): 2304–2339.

Amiti, Mary, and Jozef Konings. 2007. "Trade Liberalization, Intermediate Inputs, and Productivity." *American Economic Review* 97(5): 1611–1638.

Arkolakis, Costas, Arnaud Costinot, and Andrés Rodríguez-Clare. Forthcoming. "New Trade Models, Same Old Gains?" *American Economic Review*.

Arkolakis, Costas, Svetlana Demidova, Peter J. Klenow, and Andrés Rodríguez-Clare. 2008. "Endogenous Variety and the Gains from Trade." *American Economic Review Papers and Proceedings* 98(2): 444–450.

Armenter, Roc, and Miklós Koren. 2010. "A Balls-and-Bins Model of Trade." Working Paper. Available at http://resources.cefig.eu/papers/balls_and_bins.pdf.

Basu, Susanto, and John G. Fernald. 2002. "Aggregate Productivity and Aggregate Technology." *European Economic Review* 46(6): 963–991.

Bernard, Andrew B., Jonathan Eaton, J. Bradford Jensen, and Samuel Kortum. 2003. "Plants and Productivity in International Trade." *American Economic Review* 93(4): 1268–1290.

Bernard, Andrew B., J. Bradford Jensen, Stephen J. Redding, and Peter K. Schott. 2009. "The Margins of U.S. Trade." *American Economic Review Papers and Proceedings* 99(2): 487–493.

Bernard, Andrew B., J. Bradford Jensen, and Peter K. Schott. 2009. "Importers, Exporters, and Multinationals: A Portrait of Firms in the U.S. that Trade Goods." In *Producer Dynamics: New Evidence from Micro Data,* ed. Timothy. Dunne, J. Bradford Jenson, and Mark J. Roberts, 513–552. Chicago: University of Chicago Press.

Broda, Christian, Joshua Greenfield, and David E. Weinstein. 2006. "From Groundnuts to Globalization: A Structural Estimate of Trade and Growth." Working Paper No. 12512. Cambridge, MA: National Bureau of Economic Research.

Broda, Christian, and David E. Weinstein. 2006. "Globalization and the Gains from Variety." *Quarterly Journal of Economics* 121(2): 541–585.

Burstein, Ariel, and Javier Cravino. 2010. "Trade Liberalizations and Measured Real GDP in Models of International Trade." Working Paper. Available at http://www.econ.ucla.edu/arielb/realGDP.pdf.

Burstein, Ariel, Martin Eichenbaum, and Sergio Rebelo. 2005. "Large Devaluations and Real Exchange Rates." *Journal of Political Economy* 113(4): 742–784.

Chaney, Thomas. 2008. "Distorted Gravity: The Intensive and Extensive Margins of International Trade." *American Economic Review* 98(4): 1707–1721.

Desai, Mihir A., C. Fritz Foley, and James R. Hines. 2004. "A Multinational Perspective on Capital Structure Choice and Internal Capital Markets." *Journal of Finance* 59(6): 2451–2488.

di Giovanni, Julian, and Andrei A. Levchenko. 2010. "Firm Entry, Trade, and Welfare in Zipf's World." Working Paper No. 16313. Cambridge, MA: National Bureau of Economic Research.

Eaton, Jonathan, and Samuel Kortum. 2002. "Technology, Geography, and Trade." *Econometrica* 70(5): 1741–1779.

Eaton, Jonathan, Samuel Kortum, and Francis Kramarz. Forthcoming. "An Anatomy of International Trade: Evidence from French Firms." *Econometrica*.

Ethier, Wilfred J. 1982. "National and International Returns to Scale in the Modern Theory of International Trade." *American Economic Review* 72(3): 389–405.

Feenstra, Robert C. 1994. "New Product Varieties and the Measurement of International Prices." *American Economic Review* 84(1): 157–177.

Feenstra, Robert C., Benjamin R. Mandel, Marshall B Reinsdorf, and Matthew J. Slaughter. 2009. "Effects of Terms of Trade Gain and Tariff Changes on the Measurement of U.S. Productivity Growth." Working Paper No. 15592. Cambridge, MA: National Bureau of Economic Research.

Feenstra, Robert C., Maurice Obstfeld, and Katheryn Russ. 2010. "In Search of the Armington Elasticity." Working Paper. Available at http://www.frbsf.org/economics/conferences/1010/Feenstra.pdf.

Fernald, John, and B Neiman. 2011. "Growth Accounting with Misallocation: Or, Doing Less with More in Singapore." *American Economic Journal: Macroeconomics* 3(2): 29–74.

Ghironi, Fabio, and Marc J. Melitz. 2005. "International Trade and Macroeconomic Dynamics with Heterogenous Firms." *Quarterly Journal of Economics* 120(3): 865–915.

Goldberg, Pinelopi , Amit Kumar Khandelwal, Nina Pavcnik, Petia Topalova. Forthcoming. "Imported Intermediate Inputs and Domestic Productivity Growth: Evidence from India."

Quarterly Journal of Economics. Available at
http://www0.gsb.columbia.edu/faculty/akhandelwal/papers/gkpt_inputs_122.pdf.

Grossman, Gene M., and Elhanan Helpman. 1991. "Quality Ladders in the Theory of Growth."
Review of Economic Studies 58(1): 43–61.

Halpern, László, Miklós Koren, and Adam Szeidl. 2009. "Imported Inputs and Productivity."
Working Paper. Available at
http://resources.cefig.eu/papers/imported_inputs_and_productivity.pdf.

Hsieh, Chang-Tai, and Peter J. Klenow. 2009. "Misallocation and Manufacturing TFP in China
and India." *Quarterly Journal of Economics* 124(4): 1403–1448.

Jones, Charles I. 2011. "Intermediate Goods and Weak Links in the Theory of Economic
Development." *American Economic Journal: Macroeconomics* 3(2): 1–28.

Kehoe, Timothy J., and Kim Joseph Ruhl. 2008. "Are Shocks to the Terms of Trade Shocks to
Productivity?" *Review of Economic Dynamics* 11(4): 804–819.

Krugman, Paul. 1980. "Scale Economies, Product Differentiation, and the Pattern of Trade."
American Economic Review 70(5): 950–959.

Melitz, Marc J. 2003. "The Impact of Trade on Intra-Industry Reallocations and Aggregate
Industry Productivity." *Econometrica* 71(6): 1695–1725.

Mendoza, Enrique G. 2010. "Sudden Stops, Financial Crises, and Leverage." *American
Economic Review* 100(5): 1941–1966.

Mendoza, Enrique G., and Vivian Z. Yue. 2008. "A Solution to the Default Risk-Business Cycle
Disconnect." Working Paper No. 13861. Cambridge, MA: National Bureau of Economic
Research.

Meza, Felipe, and Erwan Quintin. 2005. "Financial Crises and Total Factor Productivity." Center
for Latin America Working Paper 01-05. Dallas: Federal Reserve Bank of Dallas. Available at
http://dallasfed.org/research/claepapers/2005/lawp0501.pdf.

Neumeyer, Pablo Andrés, and Guido Sandleris. 2010. "Understanding Productivity During the
Argentine Crisis." Business School Working Paper 2010-04. Buenos Aires: Universidad de
Torcuato di Tella.

Pierce, Justin R., and Peter K. Schott. 2009. "A Concordance Between Ten-Digit U.S.
Harmonized System Codes and SIC/NAICS Product Classes and Industries." Working Paper No.
15548. Cambridge, MA: National Bureau of Economic Research.

Sandleris, Guido, and Mark L. J. Wright. 2010. "The Costs of Emerging Market Financial Crises: Output, Productivity, and Welfare." Working Paper. Washington, DC: Inter-American Development Bank. Available at http://www.iadb.org/res/publications/pubfiles/pubS-913.pdf.

Appendix A

In this appendix we first present proofs of propositions 1 and 2 and relate single deflated and double deflated firm-level value added to each other. We start by deriving the general case with fixed costs (corresponding to proposition 2) and then note that the case without fixed costs (corresponding to proposition 1) is nested within the general case. To do this, we first show that the share of output going to intermediate input demand is independent of i:

$$\hat{z}_i = \hat{z} \equiv \frac{z_i}{Y_i}.$$

Each firm j's demand for domestic intermediate inputs produced by firm i can be shown straightforwardly to be given by:

$$z_{ji} = \left(\frac{p_i}{P_z}\right)^{\frac{1}{\theta-1}} Z_j.$$

Combining this with the above demand function for the final good g_i allows us to decompose firm i's revenue into

$$p_i Y_i = p_i g_i + p_i z_i = \left(\frac{p_i}{P_G}\right)^{\frac{\theta}{\theta-1}} P_G G + \left(\frac{p_i}{P_z}\right)^{\frac{\theta}{\theta-1}} P_z \int_j Z_j dj. \tag{11}$$

Using (6) along with the definition of γ_i gives:

$$\tilde{Z} \equiv \int_j Z_j dj = \int_j \frac{P_z Z_j}{P_{Xj} X_j} \frac{P_{Xj} X_j}{P_z} dj = \frac{\mu}{P_z} \int_j \gamma_j C_j Y_j dj.$$

Now, substituting in $p_j = \frac{1}{\theta} C_j$ (from (7)) and firm revenues in (11) gives:

$$\tilde{Z} = \frac{\mu \theta P_G^{\frac{1}{1-\theta}} G \int_j \gamma_j p_j^{\frac{\theta}{\theta-1}} dj}{P_z \left[1 - \mu \theta P_z^{\frac{\theta}{1-\theta}} \int_j \gamma_j p_j^{\frac{\theta}{\theta-1}} dj\right]}.$$

Thus, we have:

$$\hat{z}_i = \frac{\mu \theta \int_j \gamma_j p_j^{\frac{\theta}{\theta-1}} dj}{P_z^{\frac{\theta}{\theta-1}}} = \mu \theta \gamma \quad \text{where } \gamma \equiv \frac{\int_j \gamma_j p_j^{\frac{\theta}{\theta-1}} dj}{\int_j p_j^{\frac{\theta}{\theta-1}} dj},$$

which is independent of i.

Now, we can express aggregate firm revenues as:

$$\begin{aligned}
\int_i p_i Y_i di &= \int_i p_i g_i di - \int_i P_{m_i} M_i di + \int_i p_i \hat{z}_i Y_i di + \int_i P_{m_i} M_i di \\
&= P_G G - \int_i P_m M_i + \mu \theta \gamma \int_i p_i Y_i + \int_i (1 - \gamma_i) P_{X_i} X_i di \\
&= P_G \cdot VA + \mu \theta \gamma \int_i p_i Y_i + \mu \theta \int_i (1 - \gamma_i) p_i Y_i di.
\end{aligned}$$

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Note that

$$\frac{\int_i \gamma_i p_i Y_i di}{\int_i p_i Y_i di} = \frac{\int_j \gamma_j p_j^{\frac{\theta}{\theta-1}} dj}{\int_j p_j^{\frac{\theta}{\theta-1}} d_j} = \gamma \Rightarrow \mu\theta \int_i (1-\gamma_i) p_i Y_i di = \mu\theta(1-\gamma) \int_i p_i Y_i di,$$

and so

$$\int_i p_i Y_i di = \frac{P_G \cdot VA}{1 - \mu\theta}.$$

Further, combining (4), (5), and (6) with the fact that $C_i Y_i = \theta p_i Y_i$ and aggregating across firms i gives us the following expressions for aggregate spending on inputs:

$$wL_p = (1-\mu)(1-\alpha)\theta \int_i p_i Y_i di = \frac{(1-\mu)(1-\alpha)\theta}{1-\mu\theta} P_G \cdot VA,$$

$$rK = (1-\mu)\alpha\theta \int_i p_i Y_i di = \frac{(1-\mu)\alpha\theta}{1-\mu\theta} P_G \cdot VA,$$

$$\int_i P_{X_i} X_i di = \mu\theta \int_i p_i Y_i di = \frac{\mu\theta}{1-\mu\theta} P_G \cdot VA,$$

where $L_p = \int_i L_{p,i} di$, $K = \int_i K_i di$. Now, we just need to solve for aggregate $X = \int X_i di$ in terms of VA which will allow us to get an expression for VA from aggregating firms' optimal pricing and cost equations. First, note that the demand for the aggregate domestic input Z_i can be derived as:

$$Z_i = \left(\frac{P_z}{P_{X,i}}\right)^{\frac{1}{\rho-1}} X_i.$$

Additionally, note that since we've assumed that the elasticity of substitution across varieties is the same for the intermediate good and final good production technology, we will have $P_G = P_z$ and so we can write:

$$\gamma_i \equiv \frac{P_z Z_i}{P_{X_i} X_i} = \left(\frac{P_z}{P_{X_i}}\right)^{\frac{\rho}{\rho-1}} = \left(\frac{P_G}{P_{X_i}}\right)^{\frac{\rho}{\rho-1}} \Rightarrow \frac{P_G}{P_{X_i}} = \gamma_i^{\frac{\rho-1}{\rho}} \quad \text{and} \quad P_{X_i} = P_G \gamma_i^{\frac{1-\rho}{\rho}}.$$

Hence, the spending share expression for X_i becomes:

$$X_i = \mu\theta \frac{p_i Y_i}{P_{X_i}} = \frac{\mu\theta}{P_G} \gamma_i^{\frac{\rho-1}{\rho}} p_i Y_i$$

$$\Rightarrow X = \int_i X_i di = \frac{\mu\theta}{P_G} \widehat{\gamma} \int_i p_i Y_i di = \frac{\mu\theta\widehat{\gamma}}{P_G(1-\mu\theta)} P_G \cdot VA \quad \text{where} \quad \widehat{\gamma} \equiv \frac{\int_i \gamma_i^{\frac{\rho-1}{\rho}} p_i Y_i di}{\int_i p_i Y_i di}$$

$$\Rightarrow P_G = \frac{\mu\theta\widehat{\gamma}}{1-\mu\theta} \frac{P_G \cdot VA}{X}. \tag{12}$$

On the cost side, we have from (3) that

$$C_i = \frac{(r^\alpha w^{1-\alpha})^{1-\mu} P_{X_i}^\mu}{\epsilon A_i} \quad \text{where} \quad \epsilon = \mu^\mu (1-\mu)^{1-\mu} \left(\alpha^\alpha (1-\alpha)^{1-\alpha}\right)^{1-\mu}.$$

Then, the aggregate final goods price is:

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

After some rearranging, this becomes

$$
\begin{aligned}
\epsilon\theta P_G Q_{\gamma\theta} &= \left(r^\alpha w^{1-\alpha}\right)^{1-\mu} P_G^\mu \\
&= \left(\left(\frac{(1-\mu)\alpha\theta}{1-\mu\theta}\frac{P_G \cdot VA}{K}\right)^\alpha \left(\frac{(1-\mu)(1-\alpha)\theta}{1-\mu\theta}\frac{P_G \cdot VA}{L_p}\right)^{1-\alpha}\right)^{1-\mu} \left(\frac{\mu\theta\widehat{\gamma}}{1-\mu\theta}\frac{P_G \cdot VA}{X}\right)^\mu \\
&= \left(\left((1-\mu)\alpha\right)^\alpha \left((1-\mu)(1-\alpha)\right)^{1-\alpha}\right)^{1-\mu} (\mu\widehat{\gamma})^\mu \,\theta \frac{P_G \cdot VA}{(1-\mu\theta)} \frac{1}{\left(K^\alpha L_p^{1-\alpha}\right)^{1-\mu} X^\mu} \\
&= \epsilon\theta P_G \widehat{\gamma}^\mu \frac{VA}{1-\mu\theta} \frac{1}{\left(K^\alpha L_p^{1-\alpha}\right)^{1-\mu} X^\mu}.
\end{aligned}
$$

Then, replacing X with $\frac{\mu\theta}{P}\widehat{\gamma}\frac{P_G \cdot VA}{1-\mu\theta}$ from (12) and solving for VA gives us the expression in the proposition for the case of fixed costs:

$$
Q_{\gamma\theta\rho}\left(K^\alpha L_p^{1-\alpha}\right)^{1-\mu}\left(\frac{\mu\theta}{P_G}\widehat{\gamma}\frac{P_G \cdot VA}{1-\mu\theta}\right)^\mu = \widehat{\gamma}^\mu \frac{VA}{1-\mu\theta} \Rightarrow VA = \underbrace{\left((1-\mu\theta)^{1-\mu}\mu\theta^\mu\right)^{\frac{1}{1-\mu}} Q_{\gamma\theta\rho}^{\frac{1}{1-\mu}}}_{T_2}\left(K^\alpha L_p^{1-\alpha}\right).
$$

Without fixed costs we have that all firms will choose the same level of imports $\Omega_i = \Omega\ \forall i$. Thus, firms will face the same total intermediate input price $P_{X_i} = P_X\ \forall i$. This will make the share of spending on domestic intermediate inputs out of total spending on intermediate inputs the same across firms. That is, we will have

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

Using this in our expression for VA gives us the one given in the proposition for the case of no fixed costs, where now $L_p = L = \int_i L_i di$.

$$
VA = \underbrace{\left((1-\mu\theta)^{1-\mu}\mu\theta^\mu\right)^{\frac{1}{1-\mu}} \gamma^{\frac{\mu}{1-\mu}\frac{\rho-1}{\rho}} Q_\theta^{\frac{1}{1-\mu}}}_{T_1}\left(K^\alpha L^{1-\alpha}\right).
$$

The proof for firm value added follows very similar steps where we use the relation that

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$\frac{p_i}{P_{X_i}} = \gamma_i^{\frac{\rho-1}{\rho}} s_i^{\frac{\theta-1}{\theta}}$. The relation between VA at the aggregate level and firm value added is:

$$VA = \int_i \frac{p_i}{P_G} VA_i di,$$

where $\frac{p_i}{P_G} = s_i^{\frac{\theta-1}{\theta}}$ is inversely related to the size of firm i.

The firm level value added using double deflation and its relation to the single deflation case follows straighforwardly:

$$
\begin{aligned}
VA_i^{SD} &\equiv Y_i - \frac{P_{X_i} X_i}{p_i} = (1 - \mu\theta)Y_i \\
\ln\left(VA_{i,t+1}^{SD}/VA_{i,t}^{SD}\right) &= \ln\left(Y_{i,t+1}/Y_{i,t}\right) \\
\ln\left(VA_{i,t+1}^{DD}/VA_{i,t}^{DD}\right) &= \frac{\ln\left(Y_{i,t+1}/Y_{i,t}\right) - \mu\theta \ln(X_{i,t+1}/X_{i,t})}{1 - \mu\theta} \\
&= \frac{\ln\left(Y_{i,t+1}/Y_{i,t}\right) - \mu\theta \ln\left(\left(\frac{P_{X_{i,t+1}}}{p_{i,t+1}}X_{i,t+1}/\frac{P_{X_{i,t}}}{p_{i,t}}X_{i,t}\right)\left(\frac{p_{i,t+1}}{P_{X_{i,t+1}}}/\frac{p_{i,t}}{P_{X_{i,t}}}\right)\right)}{1 - \mu\theta} \\
&= \frac{\ln\left(Y_{i,t+1}/Y_{i,t}\right) - \mu\theta \cdot \ln\left((Y_{i,t+1}/Y_{i,t})\left(\frac{p_{i,t+1}}{P_{X_{i,t+1}}}/\frac{p_{i,t}}{P_{X_{i,t}}}\right)\right)}{1 - \mu\theta} \\
&= \ln\left(VA_{i,t+1}^{SD}/VA_{i,t}^{SD}\right) - \frac{\mu\theta}{1-\mu\theta}\left(\ln\left(\frac{p_{i,t+1}}{P_{X_{i,t+1}}}/\frac{p_{i,t}}{P_{X_{i,t}}}\right)\right).
\end{aligned}
$$

In the case when X_i is incorrectly measured then there is the additional term that captures the discrepancy in the true and measured price index that follows straightforwardly.

Appendix B

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, so as such is not a formal proof. We have shown that as long as λ is sufficiently high, the number of imported varieties is increasing in 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 γ_i (since P_{M_i}/P_Z is lower) and the highest M_i. Therefore, firms that cross the margin between importing and not importing and experience a 100 percent decline in imports are the firms with the highest pre-shock γ_i and lowest pre-shock M_i among importers.

For the firms that import in both periods, the elasticity of the response in γ_i to the import price change is less obvious. For these continuing importers, using the definition of

γ_i we can show that:

$$\frac{\partial \ln \gamma_i}{\partial \ln p_m} = \frac{\rho (1 - \gamma_i)}{1 - \rho} \left(\frac{\partial \ln P_{M_i}}{\partial \ln p_m} - \frac{\partial \ln P_Z}{\partial \ln p_m} \right) \tag{13}$$

$$= \frac{\rho (1 - \gamma_i)}{1 - \rho} \left(1 - \frac{\partial \ln P_Z}{\partial \ln p_m} + \frac{\theta - 1}{\theta} \frac{\partial \ln \Omega_i}{\partial \ln p_m} \right) > 0 \tag{14}$$

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

where $\widetilde{D} = \left[\left(\frac{1}{P_G} \right)^{\frac{1}{\theta - 1}} G + \int_j \left(\frac{1}{P_Z} \right)^{\frac{1}{\theta - 1}} Z_j dj, \right]$. For the second order conditions for an interior

solution to Ω_i to hold, the denominator satisfies $\left(\lambda - \mu + \left(\mu - \frac{\rho}{1 - \rho} \frac{1 - \theta}{\theta} \right) \gamma_i \right) > 0$. 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, γ_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 γ_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 increases the lower the initial γ_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 γ on raising the percent change in γ 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:

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

where

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

and

$$D \equiv \left[\left(\frac{1}{P_G} \right)^{\frac{1}{\theta - 1}} G + \int_j \left(\frac{1}{P_Z} \right)^{\frac{1}{\theta - 1}} Z_j dj, \right].$$

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

	Importer Name	Primary Industry	Primary Sector	Ave. Ann. Imports ($Millions)	Share of Imports, 2000	Share of Imports, 2002
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 Alumbrera 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 8: Argentina's 50 Largest Importers