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How firms accumulate inputs: Evidence from import switching☆

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ABSTRACT

We uncover new dynamic facts in Colombian manufacturing importers' data. First, imported input switching, a firm's simultaneous adding and dropping of foreign intermediates, is pervasive and a substantial fraction of firm's imports. Second, larger firms switch more conditional on age, whereas younger firms switch more conditional on size. Third, the number of imported varieties increases with firm age. Fourth, inputs of lower expenditure are more frequently dropped. Fifth, firms that switch more, have larger sales growth. Analogous facts also hold for suppliers. We propose a dynamic model where firms accumulate foreign suppliers and choose which heterogeneously productive intermediates to import. A firm compares each input's productivity across suppliers and keeps the best source, switching, lowering its unit cost, and growing in size. In the calibrated model, a 20% tariff reduction: (1) generates a 5.2% increase in welfare across steady states, and (2) upon impact only 76% of the gains accrue.

1. Introduction

Foreign input sourcing is important for firm productivity (Amiti and Konings, 2007; Goldberg et al., 2010; Gopinath and Neiman, 2014; Halpern et al., 2015; Antras et al., 2017). We use data from Colombian manufacturing importers and show that import switching—the simultaneous adding and dropping of imported inputs and suppliers at the firm level—is substantial, pervasive, and has patterns that depend on firms' life cycle. Our new evidence on switching yields light on how firms accumulate and upgrade their foreign inputs and suppliers, and cannot be explained by standard static sourcing models.

Specifically, we document new stylized facts on input switching—the facts for suppliers are similar. First, there is a large amount of switching of imported inputs by Colombian manufacturing firms. We find, on average, around 60% of firms switch inputs every year. Conditional on switching, and by a conservative measure, they add and drop more than 30% of their imported input value on average, and these two margins are positively correlated. On the aggregate, each of the add and drop margins is also large at about 12%, which makes it comparable to aggregate gross labor flows. Second, larger firms switch more conditional on age, whereas younger firms switch more conditional on size. Third, within-firm over time, the number of imported varieties increases. Fourth, smaller import value inputs are more likely to be dropped. Fifth, firms that switch more, have larger sales growth.

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These facts can be interpreted as firms searching for better inputs and suppliers, and substituting some inputs for others and some suppliers for others. From this perspective, suppliers can be seen as an intangible capital that firms accumulate. In fact, using within-firm over time variation, we find the number of suppliers increases gradually with importers' age. The interpretation of our uncovered facts suggests the existence of interesting dynamics on how firms accumulate suppliers and foreign input varieties.

We propose a dynamic model of how firms accumulate suppliers and increase their use of foreign inputs. The model extends the static model of endogenous choice of imported inputs in Halpern et al. (2015) by introducing dynamic accumulation of the supplier stock subject to costly adjustment. Similar to previous static import choice models, firms' production function features love-of-variety in intermediates, while imports incur a convex cost in the mass of varieties (see also Gopinath and Neiman, 2014). We extend this static import choice literature by introducing a continuum of heterogeneously productive inputs of which firms choose to import an endogenous range, similar to the "multiproduct" case in Blaum et al. (2018). We depart from these earlier papers by modeling the dynamic aspects of import choice. The number of known suppliers is a stock whose accumulation is subject to an adjustment cost, as in the classic physical capital accumulation literature. The gain from a larger stock of suppliers comes from the firm's ability to compare each input's productivity across all suppliers and keep the best, thereby reducing the unit cost of production. Since firms with a larger TFP gain more from importing, they also accumulate suppliers faster. When firms find new, more productive inputs and suppliers, they substitute them for their old and less productive ones. In a nutshell, the switching of inputs and suppliers is explained as firms reorganizing their production by changing their imported inputs and suppliers.

Our dynamic model rationalizes the aforementioned empirical findings. The observed levels and pervasiveness of switching (fact one) suggest the gains from more productive intermediates are large relative to the costs. Due to adjustment costs, firms accumulate suppliers and use more varieties only gradually over time (fact three) and, since finding better suppliers gets harder and harder, older firms switch less (fact two). Due to the complementarity between firm TFP and the gain from importing, larger firms accumulate more inputs/suppliers and switch more (facts two and three). The less productive intermediates are more likely to be replaced by a newly found better supplier (fact four). And switching to better inputs and suppliers reduces a firm's intermediate price index and its unit cost, generating sales growth (fact five).

To investigate the quantitative implications of our theory, we calibrate the model to match cross-sectional and dynamic moments of importers and their switching. Our model also predicts regression slopes that are not targeted in the calibration: (1) number of inputs on age, and of (2) firm sales growth on switching. With the calibrated model, we study the impact of a 20% lower import tariff. As a consequence, in our model, the aggregate final goods price index is 9.9% lower, and welfare increases by 5.2%. We also study the transition dynamics and find that welfare increases by 4.1% upon impact and 24% more by year ten—therefore, fully accruing the gains from trade liberalization takes substantial time.

We use two alternative models as benchmarks, to learn about dynamics and input productivity heterogeneity: we calibrate (1) the static component of our model, dispensing with the dynamic choice and fixing the supplier stock for all firms (and years) at the median of our baseline; and (2) a model with a homogeneously-productive input number accumulation subject to adjustment costs, fixing the average input productivity for all firms (and years) at the median of our baseline. These models that miss some of our facts produce substantial biases when comparing steady states: (1) relative to the static benchmark, our model produces a 42% larger final goods' price index gains because the endogenous supplier accumulation particularly benefits the larger firms; (2) relative to the homogeneous input dynamic model, our model has 36% larger final goods' price index gains because of the endogenously improved input productivity distribution. The aggregate value from supplier accumulation and input switching is large: the consumption gains in our model are 44% larger than in the static model.

We relate to the work on the relationship between firm imports and productivity. Amiti and Konings (2007) and Goldberg et al. (2010), respectively, show that reducing import tariffs lead to larger productivity gains and a larger product scope for firms. With production functions featuring love-of-variety in inputs, Halpern et al. (2015) estimate the effects of imported input use on total factor productivity for Hungarian firms, and Gopinath and Neiman (2014) study the impact of a large devaluation on the number of imported inputs and aggregate productivity. Bøler et al. (2015) study the complementarities between research and development and imports in Norway. Antras et al. (2017) show that the number of countries from which a firm's sources matters for its productivity and sales. Blaum et al. (2018) show that firm-product level domestic shares are sufficient statistics for unit costs and the gains from trade. While these papers focus on the net value of imports, we focus on the gross flows and the dynamic gains from accumulating suppliers and imported inputs.

Damijan et al. (2014) find that import switching is relevant for firm TFP growth using Slovenia's trade liberalization. Unlike them, we provide a theory that rationalizes detailed new evidence on firms' import switching behavior and we also quantify our proposed mechanism. Boehm et al. (2022) show evidence of firms' complex product expansion path for India. Like both of these papers, we argue that focusing only on the number of imported inputs disregards an important adjustment channel, i.e. gross churning, and we show how this input and supplier-related process is dynamic in nature. Kugler and Verhoogen (2012) and Bastos et al. (2018) show that input and output quality are jointly determined. We abstract from output quality to focus on firm's productivity dynamics induced by better imported intermediates.

Our findings, that switching and firm age are negatively related and that firms slowly accumulate suppliers and imported inputs, are analogous to the exporter dynamics emphasized by Alessandria et al. (2021), Arkolakis (2016), Bernard et al. (2010), Eaton et al. (2021), Fitzgerald et al. (2019), and Ruhl and Willis (2017). While these papers focus on learning about demand, within firm reallocation of resources, accumulation of a customer stock, and learning by exporting, we focus on how firms improve productivity by accumulating suppliers and upgrading inputs.[1] In Timoshenko (2015), exporters learn about their products' appeal in the presence

[1] See Verhoogen (2023) for a review on firm upgrading in developing countries.

of demand shocks, and younger exporters add or drop more because they have less information about their attractiveness to consumers. Complementary to that paper, our evidence is robust to export switching and our theoretical mechanism for firm growth is based on unit cost reductions through the accumulation of an intangible capital, suppliers.

The adoption of intermediates is also the topic of Oberfield (2018) and Carvalho and Voigtländer (2014). The former studies the endogenous formation of supply networks as a function of individual choices and how these determine micro and macro productivity. The latter study industries' adoption of intermediates to understand the evolution of the aggregate input–output networks. Also in a network context, Chaney (2014) models exporters' dynamic search for customers and suppliers, and provides a micro-founded explanation for the sharply estimated distance in aggregate gravity equations. We abstract from network issues in our model but provide a rich firm-level theory, that is consistent with new evidence regarding the dynamics of importers and their number of suppliers. A strand of the related literature studies the role of input specificity in firms' sourcing decisions (see e.g. Antràs, 2003; Boehm and Oberfield, 2020) and its impact on firm dynamics (see e.g. Boehm and Oberfield, 2022; Heise, 2017); for simplicity, we also abstract from this topic.

We also connect to the literature on "idea flows" (for a survey see Buera and Lucas, 2018), in which firms/agents search to find better production technologies and it is the number of matches that counts for improving their own production technology as in Kortum (1997).

We consider the accumulation of suppliers as one type of organizational capital, and show that the capital adjustment cost affects the life cycle dynamics of plants as in Atkeson and Kehoe (2005), Hsieh and Klenow (2014). Foster et al. (2008) focuses on firms producing physically homogeneous products and emphasizes the effects of demand shocks on survival. As they acknowledge, dynamic forces like supplier accumulation also affect firm dynamics. Furthermore, we shed light on this supplier accumulation process by showing how switching relates to firm, input, and supplier characteristics. In fact, the cross-section and over time patterns of switching of foreign inputs has similar features to the turnover of workers, see Davis et al. (2012) and Shimer (2012). Analogously, we emphasize that imported input and supplier accumulation is a costly activity that takes time, and the efficient use of inputs involves reallocation with macro implications—see Pries and Rogerson (2005) for similar arguments for the labor input.

The remainder of the paper is structured as follows. Section 2 describes our dataset and reports key aggregate and firm-level facts. Section 3 spells out the model and states the main propositions. Section 4 deals with the quantitative analysis and Section 5 concludes.

2. Empirical evidence

2.1. Data

We use two data sources. First, transaction-level data for the universe of Colombian imports, comes from DIAN, the government tax authority. The data contains information on import value, quantity, Harmonized System (HS) code at 10 digits, city and country of origin, supplier name, and the Colombian firms' tax identifier. Second, the Annual Manufacturing Survey (or EAM in Spanish), a well-known dataset available from the National Statistical Office, DANE. Using the firm identifier that is common across datasets, we merge both sources resulting in an unbalanced panel for 1994–2011. By focusing on all manufacturing firms we avoid concerns related to goods' distribution, and focus on firms that actually produce and how they choose to do so.[2]

2.2. Switching in the cross-section of importers

Our paper is about input (supplier) switching, defined as the simultaneous adding and dropping of 10-digit HS imported goods (suppliers) at the firm level during a year. Therefore, switching in one dimension is orthogonal to switching in the other dimension. Adding and dropping are defined conservatively: dropped imported inputs are those never bought by the firm again, whereas added products have never been bought by the firm before. While results are qualitatively the same with a less restrictive definition of add and drop, by being conservative we avoid an inventory explanation for switching, as in Alessandria et al. (2010).[3] We define supplier switching analogously, which we identify using detailed string information including the name, city, and country of the supplier, similar to Eaton et al. (2021). We focus on continuing importers to avoid biases from firm entry and exit. In the product (supplier) dimension, the switch number is the sum of added and dropped products (suppliers). Switch value is defined analogously, by summing the value of added and dropped products (suppliers). More information on the data construction and variable definitions can be found in the Appendix Section 6.1.

Table 1 shows that switching of imported inputs within firms is pervasive in the cross-section of firms in 2003, a midyear in our sample. On average 66% of continuing importers switch inputs, a value that increases to 94% when weighted by import value. The analogous numbers for the supplier dimension are even larger, though the supplier dimension is subject to an upward bias due to measurement error. In both dimensions, value-weighted shares are larger than their equal-weight counterparts: large importers are more likely to switch.

[2] Before restricting our sample to manufacturing firms, our dataset aggregates to virtually the same value as the DANE aggregate trade value statistics. Aggregate manufacturing trade closely tracks total Colombian trade over time, and is around 50%–60% of total value.

[3] An appealing feature of import data is that the government makes sure of the correct measurement of the industrial classification of goods at customs since their revenues from tariffs depend on it. Contrary, standard surveys that measure input use at the firm level generally suffer from status quo bias because firms obtain previous years' forms prefilled, making it costlier to add new inputs relative to increasing the value of existing ones. Taking advantage of this feature of customs data, we define products at the 10-digit HS to capture large input substitutability which is the essence of our theory.

Table 1
Percentage of importers by switching status, statistics in 2003.

	Equal weight		Weighted by firm imports	
	Inputs	Suppliers	Inputs	Suppliers
Add and drop	66	71	94.4	98.2
Only add	11	5	1.9	0.8
Only drop	13	6	2	0.3
Nothing	10	18	1.7	0.7

Note: The table displays the percentage of importers in four mutually exclusive switching activity groups between 2003 and 2004. The first two columns have all observations equally weighted, and the last two columns have each firm weighted by its import value. We exclude entering and exiting importers. Results are similar for other years.

Table 2
Switching share in firm imports, statistics for 2003.

	Equal weight		Weighted by firm imports	
	Inputs	Suppliers	Inputs	Suppliers
Panel A. Add and drop share in firm imports, average				
Add share	35	48	11	18
Drop share	34	55	13	13
Panel B. Regression slope of add share on drop share				
Slope	0.32	0.35	0.39	0.45

Note: The table displays the intensive margin of switching. Panel A displays the percentage of add and drop values between 2003 and 2004 as a share of firm import value in 2003. Panel B displays the results of an OLS regression using the firm cross-section: the dependent variable is the added value share of imports between 2003 and 2004 and the independent variable is the dropped value share between 2003 and 2004, wherein both the denominator is imports in 2003 and both are in logs. In both panels, the first two columns have all observations equally weighted, and the last two columns weights each firm by its import value. We compute moments for firms that actually use the respective margin. All moments are statistically different from zero at 1%. Results are similar for other years.

Table 2 shows two facts on the intensive margin of switching in 2003. Panel A shows that switching is not a small value within firms (equal weight) or on the aggregate (using firm import value weights). The unweighted add and drop averages are approximately 35% for inputs and 50% for suppliers, whereas import-weighted averages are 12% and 15% for inputs and suppliers, respectively. While the latter aggregate values may seem small, they are similar to those obtained for hiring and firing workers by Davis et al. (2012) and Shimer (2012), which suggests that dynamic input reallocation has potentially large aggregate consequences as in the labor literature.

Table 2, Panel B provides regression evidence that firm-level adding and dropping shares of imports are positively associated in the cross-section, and more so for the larger importers. This is evidence of substitution of some inputs for others, and some suppliers for others.[4] Tables 1 and 2 are similar for other years.

2.3. Dynamics of imported inputs, suppliers, and switching

We have determined that the extensive and intensive margins of switching are quantitatively relevant. To better understand the determinants of switching, Table 3 shows regression evidence on the role of age and firm size using within-firm over time variation and several measures of switching. We define age as time spent in the import market. To avoid introducing systematic measurement error in age, all regression tables that use importer age exclude all importers present in 1994 for all future years.

For expositional purposes, focus on columns 1 and 3, where input switching is defined in terms of imported values and numbers, respectively. First, firms with more sales switch more. Second, younger firms switch more and gradually reduce their switching as they grow older. Columns 2 and 4 show results for switching as shares of imported values or numbers, respectively. The results are similar, except the coefficient on sales: larger firms disproportionately import more relative to their switching.

Table 3 also shows results for supplier switching that are largely consistent with the results in the input dimension, although coefficients are less insignificant due to measurement error in identifying suppliers. The quantitative effects are large in both dimensions: in the first five years as an importer, the input switching number and value shares fall by 22% and 47%, respectively; the equivalent numbers in the supplier dimension are 25% and 67%.

Next, we use within-firm and across-input (supplier) variation to show that the likelihood of dropping an input (supplier) is negatively related to its size. Table 4 displays the results both for inputs and suppliers. The size variables in each dimension are

[4] This evidence contradicts a story where firms that grow mostly add and firms that shrink mostly drop inputs/suppliers. We later show further evidence against such a story—Table 6 shows that firms that add and drop grow more in sales, a result that holds even after controlling for import growth, as shown in Appendix Section 6.4.2.

Table 3
The dependent variables are switching measures for inputs and suppliers.

	Inputs				Suppliers			
	Value (1)	Value share (2)	Number (3)	Number share (4)	Value (1)	Value share (2)	Number (3)	Number Share (4)
Import age	−0.0702**	−0.201***	−0.0285	−0.0777***	−0.0621	−0.144***	−0.0205	−0.0885***
	(−2.328)	(−5.935)	(−1.307)	(−6.932)	(−1.158)	(−5.028)	(−1.077)	(−7.653)
Import age^2	0.00283***	0.0066***	0.00103**	0.00288***	0.0152	0.00271*	0.0003**	0.00277**
	(3.541)	(3.431)	(2.047)	(4.068)	(1.101)	(1.724)	(1.970)	(2.403)
Sales	0.285***	−0.276***	0.139***	−0.0698***	0.439***	−0.193***	0.211***	−0.0395**
	(5.764)	(−5.145)	(6.443)	(−3.562)	(10.53)	(−4.571)	(10.21)	(−2.196)
Constant	6.781***	4.608***	−0.360	1.545***	4.9444***	4.051***	−1.449***	1.404***
	(8.784)	(5.394)	(−1.053)	(4.926)	(7.477)	(5.992)	(−4.401)	(4.900)
Observations	6,326	6,326	6,326	6,326	6,649	6,649	6,649	6,649
R-squared	0.693	0.682	0.781	0.615	0.796	0.588	0.823	0.545
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note. The table displays the results of OLS regression. The dependent variables are based on the switching value (number) between t and $t+1$ for both suppliers and inputs: switch value (number) is the sum of the import value (number) of switched inputs (suppliers). Switch share is the value (number) switched over the import value (number) at t. Import age is defined as time spent since the year in which the firm first imported. All variables, except age, are in logs and are defined at t. The sample includes importers that switch in the respective dimension, and we drop importers that are active in 1994 in all future years to avoid measurement error in age. All regressions include firm, and year fixed effects. Heteroskedasticity-robust t-statistic in parenthesis; statistical significance *** p<0.01, ** p<0.05, * p<0.1.

Table 4
The dependent variable is a dummy variable of input (supplier) drop.

	Inputs					Suppliers				
	(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(5)
Value share	−0.0628***			−0.0632***		−0.0593***			−0.0596***	
	(−360.9)			(−362.8)		(−287.9)			(−287.7)	
Value		−0.0643***			−0.0643***		−0.0711***			−0.0711***
		(−367.0)			(−366.8)		(−286.4)			(−286.9)
Sales			−0.0113***	−0.0384***	−0.00472***			−0.00402**	−0.0323***	0.00340**
			(−8.485)	(−31.05)	(−3.838)			(−2.200)	(−18.68)	(1.973)
Constant	0.105	1.081***	0.700***	0.782***	1.164***	0.110	1.131	0.308	0.696	1.069
	(0.806)	(8.551)	(5.455)	(5.986)	(9.084)	(0.00632)	(0.105)	(0.0359)	(0.0468)	(0.109)
Observations	789,738	789,738	789,738	789,738	789,738	576,835	576,835	576,835	576,835	576,835
R-squared	0.239	0.243	0.122	0.240	0.243	0.146	0.144	0.044	0.146	0.145
Firm FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Industry*Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note. The table displays the results of OLS regression. The dependent variable is a dummy variable with value one for each input (supplier) dropped between t and $t+1$ and zero otherwise. Value is the import value of an input (supplier). Value share is the import value of an input (supplier) over the total firm import value. Independent variables are in logs and at period t. All regressions include firm and industry-year fixed effects. Heteroskedasticity-robust t-statistic in parenthesis; statistical significance *** p<0.01, ** p<0.05, * p<0.1.

(1) the purchased value of an input (supplier) or (2) its share in the firm's imported value. The stylized fact is robust to further controlling for firm's sales.

We conclude this section with Table 5, which shows that the number of inputs (suppliers) grows gradually over importer's life cycle, using within-firm over time variation. The quantitative effects are large: in the first five years as an importer, column 1 implies that the number of inputs (suppliers) grows by 32% (43%) on average.

2.4. Sales growth and switching

Next, we study the impact of switching on firm sales growth with two different specifications: firm fixed effects and the standard dynamic panel data estimator (Blundell and Bond, 1998), henceforth BB.[5]

[5] The specification using firm fixed effects is $\Delta Sales_{f,t} = \beta_0 + \beta_1 Sales_{f,t-1} + \beta_2 Switch_{f,t-1} + \alpha_f + \epsilon_{f,t}$, where $\Delta y_{t+1} \equiv y_{t+1} - y_t$, and $\epsilon_{f,t}$ is the error term and is assumed to be iid and orthogonal to the independent variables and to α_f, the firm f fixed effect. To understand the identifying assumptions of BB, note the equation can also be written as $Sales_{f,t} = \beta_0 + (\beta_1 + 1)Sales_{f,t-1} + \beta_2 Switch_{f,t-1} + \alpha_f + \epsilon_{f,t}$. BB propose a system of moment conditions that solves the endogeneity problem that $E(Sales_{f,t-1}\alpha_f) \neq 0$, handles cases with large autocorrelation in the dependent variable, and treats the independent variables as strictly predetermined ($E[Switch_{it-2}\epsilon_{is}] = 0$ only for $s \geq t$ and zero otherwise); the moments are for $k > 1$: (1) $E[Z_{f,t-k}\Delta\epsilon_{f,t}] = 0$ where $Z_{f,t} \equiv \{Sales_{f,t}, Switch_{f,t}\}$, and (2) $E[\Delta Z_{f,t-k}(\alpha_f + \epsilon_{f,t})] = 0$. Our model suggests the instruments are valid: the first set because past switching or past firm size are uncorrelated to future sales

Table 5
The dependent variables are number of inputs and suppliers.

	Inputs		Suppliers	
	(1)	(2)	(1)	(2)
Import age	0.0762***	0.0490***	0.0979***	0.0707***
	(8.377)	(6.259)	(4.606)	(3.401)
Import age^2	−0.00119**	−0.000527	−0.00145***	−0.000727*
	(−2.336)	(−1.058)	(−3.432)	(−1.770)
Sales		0.210***		0.205***
		(12.24)		(13.35)
Constant	0.953***	−2.183***	0.35	−2.596***
	(21.40)	(−8.418)	(1.553)	(−8.158)
Observations	14,154	14,154	14,154	14,154
R-squared	0.790	0.795	0.827	0.833
Firm FE	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes

Note. The table displays the results of OLS regression. The dependent variable is the number of inputs (suppliers) at time t. Import age is defined as time spent since the year in which the firm first imported. The sample includes importers, and we drop importers active in 1994 in all future years to avoid measurement error in age. All variables in logs except age, and controls are at defined time $t-1$. All regressions include firm, and year fixed effects. Heteroskedasticity-robust t-statistic in parenthesis; statistical significance *** p<0.01, ** p<0.05, * p<0.1.

Table 6
The dependent variable is sales growth.

	Inputs						Suppliers					
	(1)	(2)	(3)	(4)	(5)	(6)	(1)	(2)	(3)	(4)	(5)	(6)
Switch Value	0.00963***			0.0187***			0.0243***			0.0189***		
	(6.056)			(6.514)			(12.68)			(4.822)		
Switch Number		0.0346***			0.0685***			0.0647***			0.0753***	
		(9.692)			(8.926)			(14.91)			(7.291)	
Switch Dummy			0.0462***			0.0557***			0.0400***			0.0342***
			(7.888)			(5.832)			(6.143)			(3.250)
Sales	−0.305***	−0.311***	−0.307***	−0.117***	−0.131***	−0.096***	−0.313***	−0.320***	−0.305***	−0.118***	−0.13***	−0.12***
	(−27.09)	(−27.48)	(−27.25)	(−32.98)	(−27.97)	(−36.24)	(−26.79)	(−27.12)	(−26.40)	(−27.94)	(−29.29)	(−17.19)
Observations	34,094	34,094	38,186	28,402	28,402	31,621	33,933	33,933	35,942	26,090	26,090	27,268
R-squared	0.312	0.314	0.301				0.306	0.309	0.301			
Firm FE	Yes	Yes	Yes	No	No	No	Yes	Yes	Yes	No	No	No
First difference	No	No	No	Yes	Yes	Yes	No	No	No	Yes	Yes	Yes
Industry*Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Note. The table displays the results of OLS regression, columns 1–3, and Blundell and Bond (1998)'s generalized method of moments estimates, columns 4–6. The dependent variable is firm log sales ratio between t and $t+1$. The switching dummy is 1 when the firm has positive switch value, and zero otherwise; the three switching measures defined between t and $t+1$, controls at t. All control variables are in logs, except the switching dummy. The sample in columns 1–2 and 4–5 includes firms with positive switching, whereas columns 3 and 6 include all importers with positive switch in at least one year. Heteroskedasticity-robust t-statistic in parenthesis; statistical significance *** p<0.01, ** p<0.05, * p<0.1.

First, we use within-firm over time variation and control for industry-level aggregate shocks. Table 6, columns 1 to 3, shows that three measures of import switching—switching value, switching number, and a switching dummy—are positively associated to sales growths even controlling for firm sales, a firm fixed effect, and industry-time fixed effects. Moreover, larger firms grow less. The right-hand part of Table 6 also shows results for the supplier dimension: in columns 1–3, supplier switching measures are also positively associated with sales growth.

Second, despite our results hold for several switching measures in the input and supplier dimensions, Table 6 could still be due to reverse causality. For example, firms that grow more may also be reorganizing their production, and hence switching more. More generally, the association between switching and growth could be spurious. To deal with reverse causality and endogeneity we use the BB estimator, which uses a GMM system of instruments (for more, see footnote 5). Estimates are found in Table 6, columns 4–6 for both inputs and suppliers, and are reported to be directly comparable to those in columns 1–3. Note that coefficients have a larger magnitude when using instruments.[6]

growth after controlling for current sales and switching, and the second set because lagged growth in sales and switching do not affect future sales levels after controlling for current sales and switching. The table reports β_1 and β_2 for both specifications.

[6] Interestingly, Damijan et al. (2014) also obtain a positive association between a firm's imported input switching and its TFP growth using Slovenian importer's data for 1994–2008, using our two specifications (firm fixed effects and the Blundell and Bond (1998) estimator).

Across all columns of Table 6, the coefficients barely change when controlling for import growth (see Table 14 in Appendix Section 6.4.2), which shows that gross import flows matter for firm growth, even when controlling for net import growth.

2.5. Discussion on evidence

Timoshenko (2015) shows evidence that firms experiment and learn in the export market, thereby switching exported products in destination markets. We address this alternative mechanism in two main ways. First, the evidence we provide for supplier switching reduces these concerns: while changing the produced varieties may require changing the production function, and hence the intermediates used, it is unclear why changing suppliers would be optimal given it is costly.[7] Second, all of our regression results, Tables 3–5, are robust to adding an export switching dummy, aimed at directly controlling for output experimentation. We conduct an even more thorough robustness of Table 6—all of the results are robust to the inclusion of (1) firm import value growth concurrent with switching measures, (2) an exporter control, and (3) both, where the exporter control is either (i) an exported product switching dummy, (ii) an exporter dummy, or (iii) the export share in total sales of the firm. Robustness to Tables 3–6 are in Appendix Section 6.4. Finally, all of the dynamic results are robust to adding a first year dummy, which Bernard et al. (2017) show is important for exporter dynamics; these results are available upon request.

3. Model

The theory in this section introduces firm's accumulation of their foreign supplier stock over time, together with the adjustment of their heterogeneously productive imported inputs, by building on the static model of endogenous choice of imported inputs by Gopinath and Neiman (2014) and Halpern et al. (2015).

3.1. Consumers

There is a mass L of consumers, each of whom inelastically supplies a unit of labor in exchange for a wage w_t and also obtains his equal share in aggregate firm profits Π. With this income a consumer chooses the quantity of a final composite good C_t to maximize utility $U = \sum_{t=0}^{\infty} \beta^t \ln(C_t)$, where $C_t \equiv \left(\int_{\Omega} c_t(\omega)^{\frac{\rho-1}{\rho}} \, d\omega \right)^{\frac{\rho}{\rho-1}}$, $c_t(\omega)$ denotes consumption of each variety ω, ρ is the elasticity of demand, and Ω is the set of varieties produced by domestic firms.

The demand for each variety is given by

$$c_t(\omega) = \left(\frac{p_t(\omega)}{P_t} \right)^{-\rho} C_t, \tag{1}$$

where $P_t = \left(\int_{\Omega} p_t(\omega)^{1-\rho} \, d\omega \right)^{\frac{1}{1-\rho}}$.

3.2. Domestic firms

Firms are monopolistically competitive and each firm produces one variety $\omega \in \Omega$. To focus on firms' dynamic input decisions, we assume there is no fixed cost of production and we assume that, every period, there is an exogenous mass of entrants J, as in Chaney (2008) or Arkolakis et al. (2018), and firms exit the market exogenously with probability δ_f every period. Upon entry, firms draw permanent productivity $A(\omega)$, which in the quantitative section we assume comes from a Log-Normal distribution with parameters (μ_A, σ_A).

Each period t, firms produce using labor, ℓ, and an intermediate input bundle, x, with production function

$$y_t(\omega) = A(\omega) \ell_t(\omega)^{1-\alpha} x_t(\omega)^{\alpha}. \tag{2}$$

where $x_t(\omega) = \exp\left(\int_0^1 \ln x_{jt}(\omega) dj \right)$. In turn, each x_j is composed of a home supplied input, denoted by H_j, and an imported input denoted by M_j,

$$x_{jt}(\omega) = \left[H_{jt}(\omega)^{\frac{\sigma-1}{\sigma}} + \left(b_{jt} M_{jt}(\omega) \right)^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma}{\sigma-1}}, \tag{3}$$

where σ is the elasticity of substitution between the home and the imported input, and $b_{jt} > 1$ measures the productivity advantage of the imported input j at time t. We denote with p_H and p_F the domestic and imported input prices, respectively. While firms have free access to all domestic input suppliers, importing intermediate inputs incurs an increasing cost of $Em_t(\omega)^{\eta}$ in terms of labor, where $m_t(\omega) = \int_{j \in \Gamma(\omega)} dj$, $\Gamma(\omega)$ is the *endogenous* set of imported goods, and $\eta > 1$ renders the cost convex as in Gopinath and Neiman (2014) and Halpern et al. (2015). With this technology all firms use all the domestic inputs, and choose imported inputs based on a trade-off between the productivity gains induced by foreign inputs and the convex cost of importing them.[8]

[7] We thank an anonymous referee for the suggestion.

[8] We could have modeled domestic inputs similarly if we had access to detailed domestic input use data.

Firms maximize $\sum_{t=0}^{\infty}(\beta(1-\delta_f))^t\pi_t^{net}$, the life-time present value of π_t^{net}, per-period profits net of all costs. To simplify notation, we next focus on a stationary equilibrium where aggregate expenditure Y_t, the price index P_t, and the wage rate w_t are constant in equilibrium, and henceforth suppress the time notation on the aggregate variables. We relabel a firm ω by its states: productivity A, age a, and endogenous state variable n, which denotes the measure of imported input suppliers.

A newly born firm has age $a = 0$, enters with a permanent productivity draw A, and has no stock of foreign suppliers, that is, $n = 0$. At the beginning of every period, before production takes place, a firm with age a and supplier stock n_{a-1} decides the new stock of foreign suppliers n_a. Gains and costs determine its dynamics.

On the one hand, there are gains from increasing n. There exists a measure of foreign suppliers, each of which produces one input[9] with productivity independently drawn from a Frechet distribution $F(b)$, with support over $(1,\infty)$. Once drawn, a known supplier's input productivity b is fixed. A firm compares the draws for each input across its n potential foreign suppliers and chooses the supplier with the highest b to source, if at all. The density for the productivity of any foreign input, given n_a the current measure of suppliers, is a random variable, $\max_{n_a}\{\tilde{b}_{n_a}\}$, with cumulative density function,

$$F\left(b;n_a\right) = Prob\left[\max_{n_a}\{\tilde{b}_{n_a}\} < b\right] = F(b)^{n_a} \tag{4}$$

For tractability, we assume that $F(b) = \exp(-Tb^{-\theta})$, as in Eaton and Kortum (2002), and obtain $F(b;n_a) = \exp(-n_a T b^{-\theta})$. In this equation, the gain from increasing the stock of suppliers is apparent: n_a has the same effect as an increase in the absolute advantage parameter T, that is, raises the mean of the input productivity distribution.[10]

On the other hand, increasing the stock of suppliers is subject to adjustment costs in terms of labor given by

$$\Phi\left(n_a,n_{a+1}\right) = \frac{\phi}{\gamma}\left(n_{a+1}-(1-\delta)n_a\right)^{\gamma}, \tag{5}$$

where ϕ and γ are constants, and δ is the depreciation of the supplier stock. Eq. (5) is familiar from the physical capital adjustment cost literature (see e.g., Hayashi, 1982). In steady state, a firm's number of suppliers remains constant, therefore, its adding and dropping is stationary.

Per-period net firm profit is given by static profits π net of adjustment costs,

$$\begin{aligned}\pi_a^{net} &= \pi_a - w\Phi\left(n_{a-1},n_a\right) = \\ &p_a A\ell_a^{1-\alpha}x_a^{\alpha} - w\ell_a - \int_0^1 p_H H_{ja}dj - \int_0^1 p_F M_{ja}dj - Em_a^{\eta} - w\Phi\left(n_{a-1},n_a\right),\end{aligned} \tag{6}$$

where p_a is the firm's output price.

There are gains from importing each intermediate, due to imperfect substitution and $b > 1$, but there is a convex cost in the mass of imported intermediates. Hence, the firm ranks inputs' productivities b from high to low and imports those inputs with the highest productivity. We can relabel input j by its productivity b, and by the law of large numbers, with n' suppliers there is a $f\left(b;n'\right)$ fraction of inputs with productivity equal to b. We denote with b^* the cutoff productivity of the input the firm imports, hence $M_b = 0$ for $b < b^*$, and the measure of imported inputs is $m(b^*;n') \equiv \int_{b^*}^{\infty} f\left(b;n'\right)db$.

Given firm productivity A and a stock of suppliers n, the firm chooses labor ℓ, the quantities of domestic and foreign inputs, H_b and M_b respectively, the imported input productivity cutoff b^*, and the stock of foreign suppliers n'. Using the first-order conditions for ℓ, H_b, and M, we obtain the firm's marginal cost of production, which we denote with $\lambda(b^*;n')$.

Recursive problem A firm with supplier stock n solves:

$$V(n) = \max_{b^*,n'}\left\{\pi\left(b^*,n'\right) - w\Phi(n,n') + \beta(1-\delta_f)V\left(n'\right)\right\}, \tag{7}$$

where the per-period net profit function is Eq. (6) with output demand (Eq. (1)) and factors' optimal demands substituted, and the dependence of $\pi(.)$ and $V(.)$ on A is implicit.[11]

The first-order conditions for b^* and n', respectively, are

$$\frac{\partial\pi}{\partial\lambda}\frac{\partial\lambda}{\partial b^*} = w\eta m(b^*;n')^{\eta-1}Ef(b^*;n'), \tag{8}$$

and

$$\frac{\partial\pi(b^*,n')}{\partial n'} + \beta(1-\delta_f)\frac{\partial V\left(n'\right)}{\partial n'} = \frac{\partial w\Phi\left(n,n'\right)}{\partial n'}, \tag{9}$$

Eq. (8) states that the marginal profit gain ($\frac{\partial\pi}{\partial\lambda}$) obtained from the extra output due to the unit cost reduction from the last imported input ($\frac{\partial\lambda}{\partial b^*}$) equals the marginal static cost of importing it. Eq. (9) features, on the left-hand side (LHS), the marginal

9 In our data, from 63 to 72% of firm import value in the firm cross-section in (any) given year is explained by the number of suppliers, with the remaining 1/3 determined by the (1) average value per product and (2) average number of products per supplier. Further, a within-firm over-time import value variance decomposition shows that 87% of the variance is due to the number of suppliers. Accordingly, in our model we focus on the two largest margins, the supplier number and the value per product, and disregard the smallest margin, products per supplier.

10 Put differently, $F_{n_{a+1}}(b)$ first-order stochastically dominates $F_{n_a}(b)$, for $n_{a+1} > n_a$.

11 See Appendix Section 7.1 for a more detailed version of this problem.

static profit gain (first term) plus the present marginal value of an extra supplier in the future (second term) equals the marginal adjustment cost of accumulating an extra supplier today, on the right-hand side (RHS).

Finally, the envelope condition at n' is,

$$\frac{\partial V\left(n'\right)}{\partial n'} = w\phi(1-\delta)\left(n''-(1-\delta)n'\right)^{\gamma-1}. \tag{10}$$

Combining Eqs. (9) and (10)

$$\frac{\partial \pi(n')}{\partial n'} + \beta(1-\delta_f)w\phi(1-\delta)\left(n''-(1-\delta)n'\right)^{\gamma-1} = w\phi\left(n'-(1-\delta)n\right)^{\gamma-1} \tag{11}$$

shows the intuition for Eq. (9) more explicitly: a larger supplier stock today affects future $V(.)$ only due to lower future adjustment costs (second term on LHS). In steady state, the number of suppliers satisfies $n^* = n'' = n' = n$ and is obtained from Eq. (11).[12]

3.3. Stationary equilibrium

Let M denote the mass of operating firms, Y be aggregate output, and $h(n,A)$ be the density of firms with supplier stock n and TFP A. The equilibrium of a small open economy consist of $\{P, Y, C, \Pi, N, h(n,A), p(n,A), y(n,A), n'(n,A), b^*(n,A), \ell(n,A), H_j(n,A), M_j(n,A)\}$ such that:

- Consumers maximize their utility subject to their budget constraint, $PC = PY$, taking aggregates and firm behavior as given.
- Firms optimize choosing $\{p(n,A), y(n,A), n'(n,A), b^*(n,A), \ell(n,A), H_j(n,A),\ M_j(n,A)\}$, taking input prices and aggregates as given.
- Labor market clears: $L = \ell_P + \ell_F$, where ℓ_F includes importing costs and searching costs and ℓ_P solves $PY = \frac{w\ell_P}{1-\alpha}\frac{\rho}{\rho-1}$.
- The equilibrium mass of operating firms in every period is $M = \sum_{n,A} h(n,A)$ and is determined by exogenous entry and exit.

3.4. Optimal importing behavior

The production function, Eq. (2), implies that the firm's unit cost of production is

$$\lambda\left(b^*; n'\right) = \frac{1}{A}\left(\frac{w}{1-\alpha}\right)^{1-\alpha}\left(\frac{P_x(n')}{\alpha}\right)^{\alpha}, \tag{12}$$

where $P_x(n') \equiv \exp\left(\int_0^1 \ln\left[p_H^{1-\sigma} + I(b_j)\left(\frac{p_F}{b_j}\right)^{1-\sigma}\right]^{\frac{1}{1-\sigma}} dj\right)$ and $I(b_j)$ is an indicator function that takes value of one if input b_j is imported and zero otherwise. Furthermore,

$$P_x(n') = p_H \exp\left(\int_{b^*}^{\infty} \ln\left[s_d(b)\right]^{\frac{1}{\sigma-1}} dF(b;n')\right). \tag{13}$$

where $s_d(b) = \frac{1}{1+\left(\frac{p_F}{bp_H}\right)^{1-\sigma}}$ is the variety-level domestic input share. A lower cutoff b^*, and a larger number of suppliers n', reduce the ideal input price index P_x. The gains from importing are due to love-of-variety and quality effects, all of which are captured by the *variety*-level domestic input shares and its within firm distribution.

The theory has two predictions in line with the literature. First, firms with larger A given n have a lower cutoff b^* and import more, due to the supermodularity of the period profit function in A and x. Second, when the price of imports p_F falls, as when import tariffs are lowered, firms import more of each input due to the substitution towards the now cheaper intermediates (foreign) and away from toward the expensive ones (domestic), and also use more foreign inputs due to the now larger gains from importing (despite the convex import cost function).

3.5. Optimal switching and supplier accumulation

The theory generates simultaneous adding and dropping of imported inputs and suppliers at the firm level: while searching for better inputs, there is an accumulation of suppliers along with optimal dropping of inputs and suppliers that are less productive to the firm. Next, Proposition 1 shows this feature formally.

Proposition 1. *When a firm with state (A,n) pays the supplier adjustment cost $\Phi(n,n')$ to increase the stock of suppliers to n' optimally, the firm adds and drops simultaneously:*

1. *the optimal mass of imported inputs increases with n', $\frac{dm}{dn'} > 0$, so new inputs and suppliers must be added,*
2. *assuming γ is large enough, the imported input productivity cutoff increases with n', $\frac{db^*}{dn'} > 0$, so some previous imported inputs and suppliers are dropped.*

[12] Eq. (11) in steady state is $\frac{d\pi(n^{ss})}{dn^{ss}} = w\phi\left(\beta(1-\delta_f)(1-\delta)+1\right)(\delta n^{ss})^{\gamma-1}$.

Proof. See Theoretical Appendix in Section 7.4. ■

The intuition for the first part of the proposition is the following. Given the current stock of suppliers n, choosing $n' > n$ allows the firm to access a better input distribution: $F(.;n')$ first-order stochastically dominates $F(.;n)$. With a better distribution, the input price index is lower ($P_x(n') < P_x(n)$), and the firm imports a larger mass, $m(b^*_{n'};n') > m(b^*_n;n)$ where b^*_n emphasizes the dependence of b^* on n. Hence, for some previously not imported inputs, more productive new suppliers are found, and the firm adds new inputs and suppliers. The second part of the proposition shows that, for a large enough γ, which we assume throughout, a larger mass of imports implies a sufficiently pronounced increase in the convex cost, such that the firm drops some of the least productive inputs and the associated suppliers that were previously used, $\frac{db^*}{dn} > 0$. This proposition is consistent with the empirical evidence in Table 5 columns 1–2, which show that the number of imported inputs rises over time, and with Table 1, which shows that simultaneous adding and dropping switching is pervasive.

Optimal switching also implies that for a firm with state (A,n), imported inputs with a larger b have a longer duration than the less productive ones. Intuitively, the firm ranks imported inputs by how productive they are. Since new draws are independent of the existing realizations, the currently used inputs that are least productive are more likely to be dropped by the firm. The empirical counterpart of this result is Table 4, which shows that imported inputs and foreign suppliers of larger value are less likely to be dropped.

Proposition 2 states that optimal switching increases with A given n, and falls with n given A.

Proposition 2. *The marginal increase in profits from an extra supplier is*

1. *larger for a higher A, given n: $\frac{d^2\pi}{dn\,dA} > 0$,*
2. *smaller for a higher n, given A: $\frac{d^2\pi}{dn^2} < 0$.*

Proof. See Theoretical Appendix in Section 7.5. ■

The first part of Proposition 2 formally shows that conditional on n, firms with larger A have more incentives to search. This is because of the complementarity between A and $P_x(n')$ in reducing unit cost (see Eq. (12)). The second part of Proposition 2 shows that there are decreasing returns to increasing n. Intuitively, as firms increase their stock of suppliers, they increase the mass of imported inputs because the distribution improves ($\frac{df(b;n')}{dn'} > 0$ for large b), thereby lowering production costs and increasing profits, $\frac{d\pi}{dn'} > 0$. However, the distribution is such that, over time, it becomes harder to find more productive suppliers for a given input, $\frac{d^2 f(b;n')}{dn'^2} < 0$ for large b. Hence, with a larger stock of suppliers, the profit gain from an extra supplier is smaller, $\frac{d^2\pi}{dn^2} < 0$. Consistent with this proposition, Table 3 shows that larger firms switch more value and numbers, and that switching declines with age.

Proposition 2 has a direct bearing on the optimal supplier accumulation policy:[13]

Proposition 3. *Supplier accumulation, $n' - (1-\delta)n$, is*

1. *higher for higher A, given n: $\frac{d(n'-(1-\delta)n)}{dA} > 0$,*
2. *smaller for a higher n, given A: $\frac{d(n'-(1-\delta)n)}{dn} < 0$.*

Proof. See Theoretical Appendix in Section 7.6. ■

For the first part, note that both profits and the value function are increasing with A given n. Hence, a larger marginal adjustment cost is optimal due to Eq. (9). This immediately implies more supplier accumulation due to the convexity of $\Phi(.)$. The proof for the second part is more involved because both the gain and the adjustment cost decline with n. A strictly concave profit function and a strictly convex adjustment cost suffice for the proof.

The proposition implies that (1) with a larger n given A there is less supplier accumulation, which implies fewer productivity draws and fewer newly added imported inputs and suppliers, and (2) with a larger A given n, more add numbers occur. The empirical evidence in Table 3 is consistent with the theoretical result: (1) larger firms switch more conditional on age, and (2) older firms switch less conditional on sales. The proposition is also consistent with Table 5 columns 3–4: the number of suppliers grows over time but at a decreasing rate, a result that is also consistent with Proposition 2.

3.6. Discussion on theory

Timoshenko (2015) proposes a model rationalizing firm dynamics through learning about demand in the export market. In our model, firms' import choice generates a productivity improvement, whereas learning in output markets is related to sales growth. Empirically disentangling the extent to which each of these two heterogeneity forces drives firm size dynamics is far from trivial. Incidentally, Foster et al. (2008) conclude that demand is an important firm sales growth driver, yet acknowledge that their results

[13] While we do not pursue a characterization of shrinking firms, the model can capture their dynamics: introducing shocks to firm TFP A over time implies that, if these were negative and persistent enough, the firm would optimally allow its supplier stock to depreciate.

can be interpreted as driven by customer-supplier relations and their evolution over time. Our model describes one aspect of those relations: the search for and accumulation of better suppliers.

In our data, we find that firms increase the number of suppliers and inputs over the life cycle, which according to the model implies a declining pattern for firm sales growth over time. Similar to Atkeson and Kehoe (2005) or Hsieh and Klenow (2014), who attribute firm growth to intangible capital accumulation, we focus on one specific type of intangible: the supplier stock.

An alternative modeling choice for our facts would be one in which there is learning about input productivity, applying Timoshenko's learning in the output dimension to the (imported) input side. Interestingly, such a model would not be able to generate changes in relative spending across inputs within firms over time, nor simultaneous adding and dropping of products within firms over time. These features are present in our model. A limitation of our approach is that it does not generate firm-input size dynamics. As detailed in footnote 9, this is a quantitatively small margin to explain the variance of import value.

To generate simultaneous adding and dropping of inputs, a learning-based theory would need firm-input-specific learning about productivity b. We do not pursue this learning approach for two reasons. First, disentangling our model from such an alternative is difficult and subject to the details of the assumed formal ingredients. Second, given we are modeling imports, each input's realized b affects firm productivity and pricing, and therefore the general equilibrium. Moreover, with firm-input specific learning on b, and different from learning about export demand, each input's imported quantity also depends on all other inputs' learning. This feedback loop complicates the model dramatically, particularly the quantitative section in which we calibrate a general equilibrium and compute the transition path to a lower p_F steady state. Yet another modeling approach would feature learning about suppliers and have a similar effect as our mechanism: better matching of firms and suppliers. We acknowledge that some of our supplier stock adjustment costs may be due to information frictions; distinguishing the two mechanisms requires more detailed data or better identification strategies.

4. Quantitative analysis

In the model, there are three sets of parameters. The first set includes population, number of entrants, the price of domestic intermediates and the absolute advantage parameter, $\left(L, J, p_H, T\right)$, which are normalization parameters in the same vein as Arkolakis et al. (2018).[14] Using the wage rate, w, as numeraire, we solve for the aggregate output price index P, using the labor market clearing condition.

The second set of parameters is obtained from outside data. We set the elasticity of demand, ρ, to 5 as in Gopinath and Neiman (2014) and Fieler et al. (2018) and the discount rate, β to 0.95 like Arkolakis (2016). We set the elasticity of substitution between H_j and M_j, σ, to 4 exactly as in Gopinath and Neiman (2014) and similar to Halpern et al. (2015, Table 3), who estimate a value of 4.006. We set the shape parameter of the input productivity distribution, θ, to 1.268 as in Antras et al. (2017, Table 4). The share of intermediates, α, is 2/3 as in Gopinath and Neiman (2014) and close to 0.7 in Fieler et al. (2018). The average annual exit rate of importers in our data is 0.15, and is the value we use for the exogenous death rate, δ_f.

The third set of parameters is chosen to match several moments of our data which are shown in Table 7. As in Arkolakis et al. (2018), a rigorous identification argument is not available due to the complexity of our model, but we next give an informal argument of how each parameter is associated with data moments. p_F is linked to the import share: a higher p_F implies a lower import share. We match it to the median value in the importer cross-section in 1995. The level parameter of the adjustment cost function, ϕ, affects add and drop levels: the higher ϕ, the lower average add and drop. We associate it with the average add and drop number share from Table 2. Parameters γ, which determines the convexity of the adjustment cost, and δ, the depreciation of the supplier stock, are both associated with the speed of supplier accumulation. We match them to the add and drop coefficients on age and age^2 in Table 3. The static convex import cost function is determined by E (level) and η (curvature), which are associated with the mean of log imports minus log sales and with the standard deviation of log imports, respectively. Finally, we use a grid for TFP, A, based on the Log-Normal distribution with parameter σ_A, which we calibrate with the standard deviation of log sales. μ_A only scales the equilibrium price and level of welfare, but all the moments are the same; therefore, we use normalization parameter $\mu_A = -0.35$.

We also calibrate two alternative models, we call them *static* and *homogeneous b* models. First, the *static* model is an extension of Halpern et al. (2015) to the case of heterogeneously productive inputs, which by contrast to our baseline informs about the role of dynamics. In this model, the intermediates' price index is $P_x = p_H \exp\left(\int_{b^*}^{\infty} \ln\left[s_d(b)\right]^{\frac{1}{\sigma-1}} \, dF(b;\bar{n})\right)$, and firms choose imports taking $\bar{n}$ as fixed. The dynamic moments are not used for its calibration, the distribution for b is the same as in our baseline, and $\bar{n}$ is set to the median number of suppliers obtained for the baseline calibration to allow better comparability across models. The static model has parameters E and η which are identified using the mean log import value minus log sales and the dispersion of import values, respectively.

Second, the *homogeneous b* model is our model but with homogeneous input productivity b across firms and time, which we set to the median b across firms in our baseline, denoted $\bar{b}$; by contrast to our baseline, this model informs about the role of imported input heterogeneity. In this model, there is no input adding and dropping, and n is the *endogenous* stock of suppliers and also the measure of imported inputs, and is the only source of import heterogeneity. In this model, the intermediates' price index is $P_x(n') = p_H \exp\left(n'\right)\left[s_d(\bar{b})\right]^{\frac{1}{\sigma-1}}$, and firms choose n' over time given the fixed foreign input quality $\bar{b}$. We keep E and η at the values calibrated for the baseline for comparability of the static import choice. Therefore, adjustment cost parameters ϕ and γ are associated

[14] L and J are scale parameters. Given T and p_H, p_F is estimated and reflects the quality-adjusted relative price of the foreign input.

Table 7
Calibration: parameters and moments.

			Baseline	Static	Homogeneous b
Panel A: Parameters					
Foreign input price	p_F		2.2	1	1.5
Adjustment cost– scale	ϕ		4.5		8
Adjustment cost– shape	γ		3		2
Depreciation of the supplier stock	δ		0.3		0.25
Static convex cost of importing– scale	E		13	12	13
Static convex cost of importing– shape	η		5.5	2.2	5.5
Dispersion of TFP	σ_A		0.36	0.37	0.37
Panel B: Moments		*Data*			
Median import share		0.17	0.15	0.17	0.17
Average switch number		0.36	0.3		
Switch on age coefficient		−0.077	−0.136		
Switch on age^2 coefficient		0.003	0.005		
Import number on age coefficient		0.076	*0.094*		0.071
Mean of log(imports)-log(sales)		−4.19	−2.46	−2.44	−2.58
Std. of log(imports)		2.51	2.54	2.25	2.20
Std. of log(sales)		1.62	1.84	1.63	1.54
Panel C: Aggregates					
Consumption in high p_F steady state			15.45	16.57	14.51
Price index, change in percent between steady states			−9.9	−5.7	−6.3
Welfare change in percent between steady states			5.2	3.6	2.9

Note. In Panel B, switch refers to switch number share and data moments are for 1995 except the regression coefficients of (1) add and drop on age and age^2 from Table 3 and (2) number on age from Table 5. In Panel B, moments in italics are not targeted in the calibration.

to the level and dispersion of imports, respectively. δ is linked to the speed of the accumulation process and we use the regression coefficient of age on the number of inputs as a target. In all models, p_F is calibrated with the median import share. In summary, our calibration strategy has the advantage that the dynamic homogeneous b model does not target input switching but only input accumulation, and the static model targets neither input accumulation nor switching.

Table 7, Panel B, shows the targeted moments. The three models match the moments well even though the alternative models have less heterogeneity. Aggregate consumption is similar across models allowing a comparison of their welfare changes in the counterfactual experiment.

4.1. Quantitative fit

Fig. 1 displays the dynamics over age in a stationary equilibrium for firms with A in percentiles 99, 90, and 50. Over time, the supplier stock and the import share of intermediates increase, incentives to add and drop suppliers decrease, and the unit cost falls. These results are consistent with the regression evidence in Section 2. Firms with larger A have their supplier stock and import share grow faster when young, reducing their switching share and their unit cost by more in their early ages.

To provide external validation, we show two regression coefficients in which the model and data are quantitatively close. In Table 7, the importer age on the input number coefficient is untargeted in the baseline. Reassuringly, we obtain 0.094 close to 0.076 in the data, and therefore our calibration strategy captures well this important aspect of firm dynamics.

Also, our model implies that over time, firms switch to more productive intermediates, reducing their costs, and causing sales growth. We can therefore study this issue quantitatively.[15] Table 8 shows that the switching number share is positively associated with firm sales growth, both in the model and in the data. The GMM-IV estimates are closer to the causal impact as the IV deals with the endogeneity in the OLS regression, which implies the data and the model slopes are quantitatively close.

In the empirical evidence Table 3, we showed that larger firms switch more volume but switch less as a share of import value. The model is in accordance with this fact: Fig. 2 shows that a firm in the 50-th percentile A switches less in numbers that a firm in the 90-th percentile A, but the former switches more as a share than the latter.

[15] We do not have a closed-form expression connecting a firm's unit cost changes to switching. Similar to Blaum et al. (2018), in our production function ignoring input productivity heterogeneity biases the unit cost upward. The static assumptions in this theory are closely related to the heterogeneous input case in Blaum et al. (2018), hence it would be enough to measure all the $s_D(b)$, and weight them appropriately, to obtain the impact on sales growth of our mechanism for unit cost reductions. However, this detailed data is rarely observed. Contrary, firm-level adding and dropping data is easily constructed from widely available import transaction data, which together with the model, allow us to calibrate the model and quantify unit cost reductions.

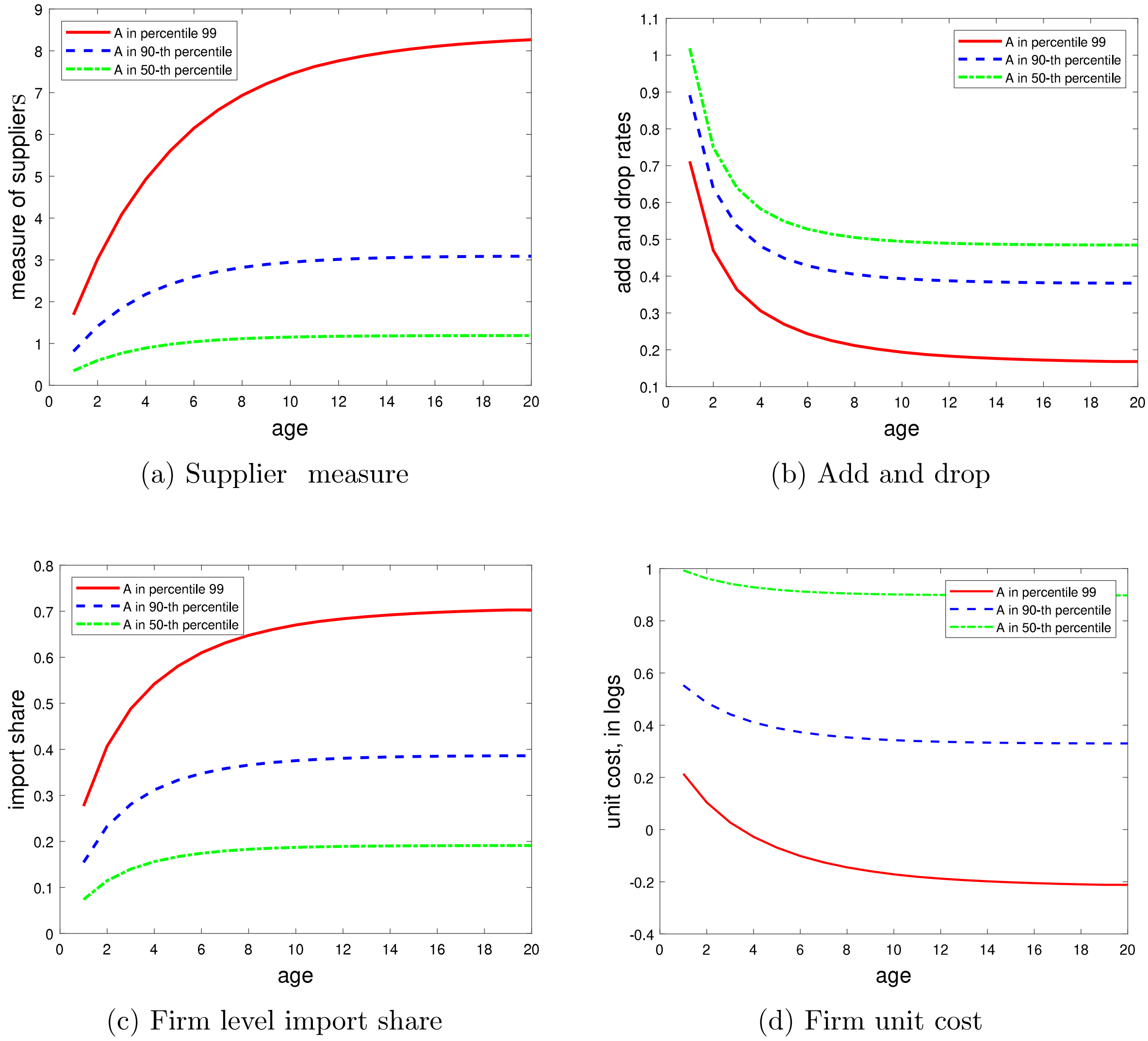


Fig. 1. Firm dynamics in steady state.

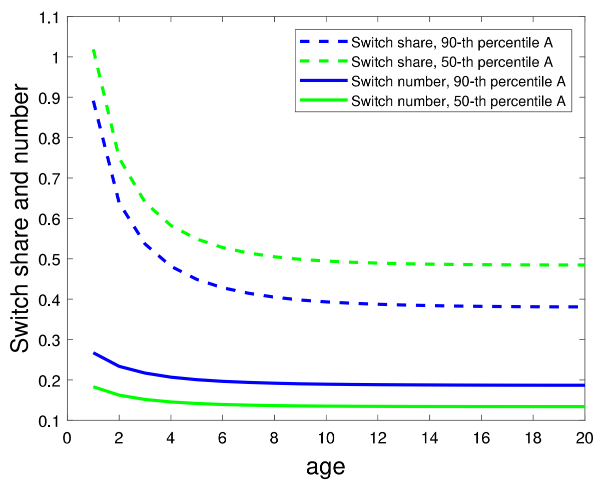


Fig. 2. Switch share and switch number for firms with A in 90-th and 50-th percentiles.

Table 8
The dependent variable is sales growth.

	Data				
	Input		Supplier		
	OLS	GMM-IV	OLS	GMM-IV	Model
	(1)	(2)	(1)	(2)	(5)
Switching number share	0.0171***	0.0385***	0.0272***	0.0345***	0.049***
	(4.779)	(5.753)	(6.313)	(4.703)	(212.97)
Observations	34,094	28,402	33,933	26,090	168,492
Firm FE	Yes		Yes		Yes

Note. The table displays the results of the OLS and GMM-IV specifications in columns 1 and 2, respectively, for both inputs and suppliers, and the calibrated model counterpart is in column 5. The dependent variable is sales growth, defined as the log of the ratio between the variable at $t+1$ over the variable at t. The independent variable is the import switch number between t and $t+1$ over the import number in t. The data sample includes importers that switch in the respective dimension. Heteroskedasticity-robust t-statistic in parenthesis; statistical significance *** p<0.01, ** p<0.05, * p<0.1.

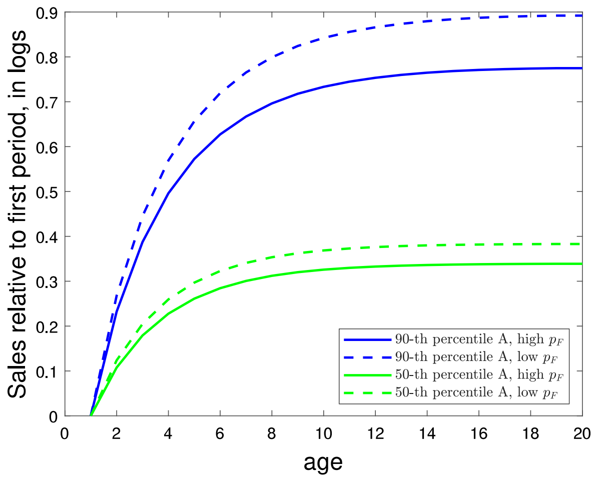


Fig. 3. Sales growth in high and low p_F steady states for firms with A in 90-th and 50-th percentiles.

4.2. Consequences of a trade liberalization

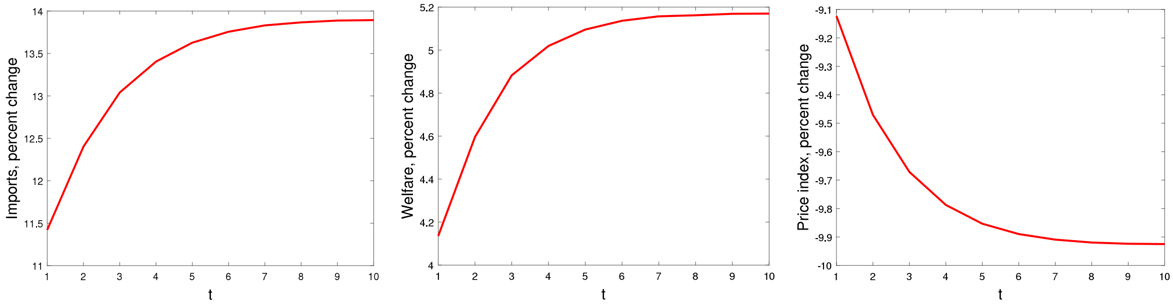
With a 20% decrease in foreign price, the steady state properties of firm's dynamics are different. Fig. 3 shows that, with a lower import price both the static and the dynamic choices are affected: sales growth due to the accumulation of suppliers is faster and reaches a larger number of suppliers at older ages. With a lower import price and more suppliers, a firm uses a larger import share to produce, and its unit cost is lower. Quantitatively, the figure shows that sales of the median A firm grow 31% (35%) between period 1 and period 10 in the old (new) steady state, implying a 13% larger growth rate when p_F is low. A firm with A in the 90th percentile grows by 73% (84%) between period 1 and period 10 in the old (new) steady state, implying a 15% more growth in the low p_F steady state.

As shown in Table 7, aggregate consumption across steady states in our model rises by 5.2% and the price index is 9.9% lower. The former responds less in absolute terms than the latter due to static convex import costs and supplier adjustment costs.

4.2.1. Transition dynamics

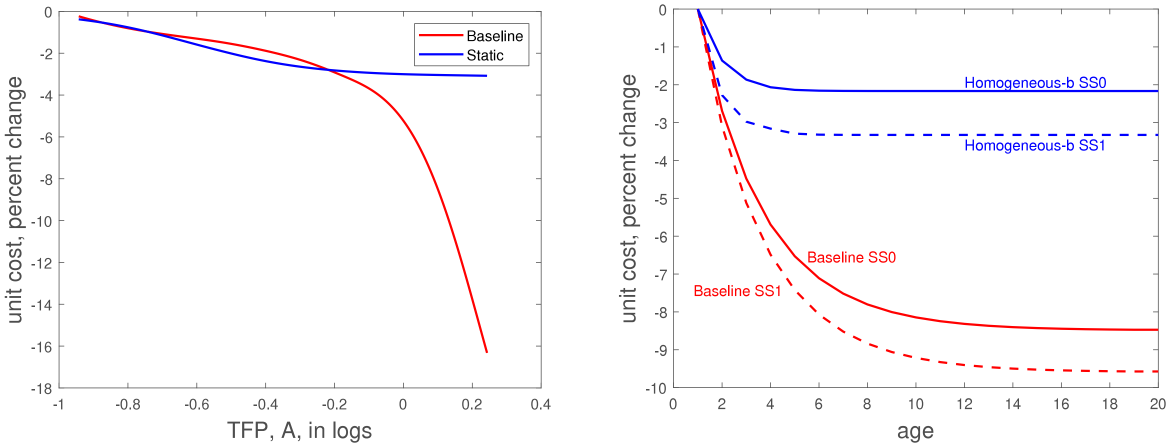
We compute the transition dynamics from a surprise implementation of the above trade liberalization. We solve for the transition path of the economy starting from the first period in which the lower tariff is implemented until the new stationary equilibrium is reached. Appendix Section 8.1 describes our methodology. The comparison of welfare gains in the above section overstates the welfare impact of the policy as the full benefits from larger supplier stocks, and lower input prices, require spending in adjustment costs that have to be paid along the transition.

Fig. 4 shows the transitional dynamics for aggregates. With a lower import price, aggregate imports upon impact are about 11% more than imports at the initial steady state and, by further supplier accumulation, reach 13% by year ten. Aggregate consumption at period $t = 1$ is 4% larger than consumption at the initial steady state, and gradually increases over time up to 5.17% after 10 years, consistent with the results in the previous section. Transitional dynamics are quantitatively relevant since welfare increases by 24% more by year ten. The price index falls at impact about 8% and declines 9% more by year tennumbers seems a little different from the figures. The true gains from the policy take substantial time to fully accrue.



(a) Import value (b) Welfare (c) Final goods' price index

Fig. 4. Aggregates in the transition across steady states.



(a) Unit cost in final over initial steady states in the firm TFP cross-section, $\lambda(n^{ss_{new}}; A, P^{ss_{new}})/\lambda(n^{ss_{old}}; A, P^{ss_{old}})$

(b) Unit cost change relative to age 1 in each steady state for the median A firm, $\lambda(n_a^{ss}; A, P^{ss})/\lambda(n_1; A, P^{ss})$

Fig. 5. Unit cost across steady states: comparison to alternative models.

4.2.2. Alternative models

The two alternative models that we calibrate in Table 7 help illustrate the role of dynamics and input productivity heterogeneity. To learn about the role of dynamics, Fig. 5(a) shows the unit cost reduction in the cross-section of A for both our model and the "static" model. First, note that both models produce unit cost reductions that are increasing in A, because importing and A are complementary. Second, the bias from ignoring supplier stock dynamics is large: for the largest firm, allowing supplier accumulation reduces the unit cost about two times more than the static model that has fixed n.[16]

To learn about the role of input heterogeneity, Fig. 5(b) shows, for the median A importer, the unit cost change relative to age one in both steady states for our model and the homogeneous-b model. The discrepancy between them is large: our model produces 3.6 (2.6) times more growth between birth and age twenty in the old (new) steady state than the model with homogeneous-b, due to the improved input productivity distribution; for a firm with an A in the 90-th percentile, the corresponding numbers are 14 and 12.

The welfare and price index changes in the static model are 3.5% and −5.7%, whereas in the homogeneous-b model, they are 2.9% and −6.3%, respectively. Both models that do not match our facts yield quantitatively meaningful biases since the equivalent numbers in our model are 5.2% and −9.9%. Given a model, the welfare change is lower than the price change (in absolute value) due to the costs associated with the sourcing policy: in our model and in the homogeneous-b model, due to static convex import and supplier adjustment costs; in the static model due to the former costs.

The largest firms in our model gain more than in the static model by accumulating suppliers, and relative to the homogeneous-b model by switching to the more productive inputs. As a consequence, both alternative models predict that the price change across

[16] Because the calibration of the static model uses the median n, the discrepancy with our model rises with A.

steady states is smaller in absolute value than our model. The calibrated costs needed to achieve these gains imply that welfare gains in our model are also larger. On the aggregate, the value of accumulated suppliers is large: the welfare gain in our model with dynamics is 44% larger than in the static model.

5. Conclusion

This paper identifies new empirical facts in foreign supplier and input switching behavior of importers and develops a dynamic model of import choice to explain them, both qualitatively and quantitatively. To construct our new evidence, we combine firm-level information from the customs transaction-level import data and the manufacturing census of Colombia. We document five new facts. First, switching, the simultaneous adding and dropping of intermediates at the firm level, is pervasive and not a small fraction of firm imports. Second, larger firms switch more conditional on age, whereas younger firms switch more conditional on size. Third, the number of imported varieties increases with a firm's age. Fourth, inputs of smaller import value are more likely to be dropped. Fifth, firms that switch more, have larger sales growth. These facts also hold for suppliers.

To rationalize these facts, we extend the static model of Halpern et al. (2015) to a continuum of heterogeneously productive imported intermediates and also allow a dynamic choice of supplier stock accumulation subject to adjustment costs. Given a stock of suppliers, a firm compares each input's productivity across its known suppliers and keeps the best source, thereby switching, lowering their unit cost, and growing.

Finally, we calibrate the general equilibrium of the model to our data and obtain the steady state and transitional implications of a 20% import tariff reduction. We show that fully accruing the gains from a trade liberalization takes ten years, and is costly. Therefore, like capital accumulation and worker reallocation, supplier accumulation is important for firm dynamics and aggregate welfare. Our findings and supply-side theory are complementary to the literature that focuses on demand mechanisms to explain firm growth (see e.g. Timoshenko, 2015).

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

https://data.mendeley.com/datasets/sw2mcmkwz9/2.

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Appendix A. Supplementary data

Supplementary material related to this article can be found online at https://doi.org/10.1016/j.jinteco.2023.103847.

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