Firm dynamics and trade*

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This Draft: October 2020

Abstract

We review the literature that studies the dynamics of firms in foreign markets, both at the intensive and extensive margins, and their aggregate implications. We first summarize a set of micro facts on exporter entry, expansion, contraction, and exit and macro facts about the response of aggregate trade flows to trade-policy and business-cycle shocks. We then present the canonical model developed in the literature to account for these facts and discuss its connection to the empirical evidence. We show how three model features — future uncertain profits, an investment in market access, and high depreciation of that access upon exit — generate transition dynamics and long-run aggregate outcomes from a cut in tariffs. The model and its extensions contribute to our understanding of the dynamics of trade integration and the evolution of future trade barriers. We discuss the key challenges faced by the canonical model, possible extensions, and applications of the framework to recent global events.

*We thank Fernando Leibovici, Roman Merga, Virgiliu Midrigan, an anonymous referee, and the editor for valuable comments on an early draft. Oscar Avila, Shizuka Inoue, and Shafaat Khan provided excellent research assistance.

1 Introduction

We review the literature on firm dynamics and trade, which has generally approached two broad sets of questions. The first set is concerned with understanding firm dynamics in trade along the extensive and the intensive margins. How do technology, trade barriers, uncertainty, and learning help explain the observed exporter life cycle and entry and exit patterns? A second set of questions asks how firm-level behaviors affect aggregate outcomes. How do the welfare gains from trade liberalization depend on firm-level behavior? Do models with firm-level dynamics help us understand the long- and short-run behavior of aggregate trade in response to changes in tariffs or over the business cycle? What explains the delayed response of the trade balance to a change in the real exchange rate?

We start by presenting a set of facts about firm export behavior and aggregate trade dynamics, organizing our approach around the extensive and intensive margins of trade. Export entry rates increase and exit rates decrease with past exporting activity and export intensity increases with time in the exporting market. We further decompose the intensive margin by destination and find that, across individual destinations, past export participation has a similar impact on exporter entry and exit. We summarize the high-frequency data and show how individual firm shipments determine exporter growth. Finally, we discuss the patterns in the aggregate data and find that the long-run response of aggregate trade to changes in trade policy is larger than the short-run response.

Motivated by several of these empirical facts, a canonical model of export dynamics has developed in the literature. In this model, a firm facing a stochastic flow of potential profits from exporting must make an upfront investment — a sunk cost — and a per-period fixed maintenance cost to access the market. Skipping this maintenance cost leads the investment to fully depreciate. This approach is closely related to the closed-economy model in Hopenhayn (1992). These three features — an uncertain future return, an upfront investment in market access, and steep depreciation of that investment — goes a long way in accounting for some of the firm behavior observed in the data, especially the persistence in export status, low entry and exit rates, and their dependence on past activity. This model also generates the differing short-run and long-run responses of aggregate trade to changes in trade policy. Researchers have built upon the canonical model by adding other types of frictions that further shape the trajectory of exporters. These models replace the large upfront cost with repeated but riskier investments at the market-, product-, or customer-level. We discuss how these extensions help explain other empirical observations and how they change key implications of the canonical model.

The firm dynamics and trade literature was born from questions about the behavior of aggregate variables, but few studies have incorporated the frictions identified in the micro literature into general equilibrium models.[1] These papers use the micro data to discipline the extra parameters in the firm's more-complex decision problem and consider the aggregate outcomes from a broader set of shocks to trade policy and business cycles. We show that static models of trade do not approximate the steady state of dynamic models and that the welfare gains from a tariff cut are much larger in models with firm dynamics. The specification of firm-level export technologies is the key driver of these findings. In an extension of the model in which goods are storable (firms hold inventories), we find that a shock leads to very different outcomes in the short-run. Getting the micro details correct changes our understanding of macro phenomena.

Our review is organized around data, models, and the interplay between the two. In section 2, we present facts about firm export behavior and aggregate fluctuations that motivate the canonical model and its extensions in section 3. In section 4, we discuss how to embed these partial equilibrium models in general equilibrium and we evaluate the aggregate effects of a trade liberalization. Section 6 discusses areas of future research and concludes.

2 Firm-level and aggregate facts

In this section, we discuss the salient features of firm and aggregate trade dynamics in the data.[2] We focus on firm-level facts that help us identify the frictions that impede trade (and

[1] Motivated by the slow reversal of the U.S. trade balance following the depreciation of the dollar in the 1980s, Baldwin (1988) and Baldwin and Krugman (1989) proposed a role for market-specific investments in product design, distribution, branding, etc., which they modelled as a sunk cost.

[2] Many data sets take the establishment as the unit of observation, while a few are organized at the firm level. For expositional ease, we will refer to both kinds of data as being made up of *firms*.

the gains from trade) and the ways that firm-level dynamics affect the aggregate economy.[3] The aggregate facts document important phenomena that we would like to explain, such as the aggregate effects of business-cycle and trade policy shocks, and represent the ongoing synthesis of international trade and macroeconomics.

2.1 Cross-sectional moments

We organize our analysis around a decomposition of the sales and export data of N firms. We order firms so that only the first $i = 1, \ldots, n$ firms have positive export intensity, $exs_{it} = exports_{it}/sales_{it}$, and derive an accounting identity for the share of total sales that is exported,

$$\frac{\sum_{i=1}^{n} exports_i}{\sum_{i=1}^{N} sales_i} = \frac{n}{N} \times \frac{n^{-1} \sum_{i=1}^{n} sales_i \times exs_i}{n^{-1} \sum_{i=1}^{n} sales_i} \times \frac{n^{-1} \sum_{i=1}^{n} sales_i}{N^{-1} \sum_{i=1}^{N} sales_i}. \tag{1}$$

The first term on the right-hand side of (1) is the *extensive margin*. It measures the share of firms that export. The second term is the *intensive margin*, which measures the average share of total sales that is exported, conditional on exporting. The third term, the *exporter premium*, measures the relative size of exporters compared to all firms.

We summarize these margins for the United States and Colombia in Table 1: there are few exporters; exports are a small share of an exporter's total sales; and exporters are relatively large. In the remainder of this review, we focus on Colombia, as the data are easy to obtain and widely used. We include the U.S. data to stress the generality of the results. Similar facts have been documented in countries big and small, rich and poor (ISGEP, 2008).[4]

The 1983–2013 and 1987–2007 periods were times of significant global integration in Colombia and the United States; Trade almost doubled in the United States and nearly tripled in Colombia. As policy and non-policy barriers fell, the extensive and intensive

[3] We focus on the export decision, as research on this margin is most developed, but there is a nascent literature on the dynamics of multinationals, importing, and the interactions of these decisions (Kasahara and Lapham, 2013; Fillat and Garetto, 2015; Gumpert et al., 2018; Imura, 2019).

[4] When comparing Colombia and the United States, we need to adjust for data coverage. The U.S. data cover firms with more than 100 employees while the Colombian data cover firms with more than 10 employees. When we restrict the Colombian data to include only firms with more than 100 employees, the extensive margin rises and the exporter premium falls to levels similar to those found in the United States.

Table 1: Decomposing the export-total-sales ratio

	United States			Colombia		Colombia 100+		
Panel A	1987	2007	log diff.	1983	2013	1983	2013	log diff.
Export/sales	6.3	11.6	61.1	5.2	14.6	5.2	13.9	97.7
Extensive	43.2	63.0	37.7	10.8	24.6	36.5	59.8	49.5
Intensive	9.9	15.5	44.9	12.8	23.5	10.8	20.3	62.8
Premium	148.0	119.5	−21.4	374.9	252.4	132.1	114.2	−14.6
Panel B								
Starter rate	10	–		2.0	5.5	6.9	13.8	
Stopper rate	17	–		16.5	16.1	11.9	10.1	

All values are expressed as percentages. The variables in panel A are defined in (1) and the variables in panel B are defined in (2). For Colombia, to alleviate noise in the data, the moments are averages over 1983–1984 and 2013–2014. The U.S. moments, from Alessandria and Choi (2014b) and Bernard and Jensen (1999), are based on the U.S. Census of Manufactures. The U.S. stopper rates are averages from 1984–1992.

margins grew. This integration brought smaller firms into exporting, which reduced the exporter premium. What cannot be seen in Table 1 is the slow adjustment of the extensive and intensive margins. We discuss the dynamics of this adjustment next.

2.2 The extensive margin

The literature on exporter dynamics has focused largely on understanding the forces that drive firms into and out of the export market. The number of exporters in a country can be described by the following laws of motion:

$$n_{t+1} = \gamma_{t+1}^{\text{starter}} \left[\delta_{nt}(N_t - n_t) + N_{E,t+1}\right] + \left(1 - \gamma_{t+1}^{\text{stopper}}\right) \left[\delta_{xt} n_t\right] \tag{2}$$

$$N_{t+1} = \delta_{nt}(N_t - n_t) + \delta_{xt} n_t + N_{E,t+1}, \tag{3}$$

where δ_n and δ_x are the survival rates of firms and N_E is the number of new firms. The first term in the right-hand side of (2) is the flow into exporting by last year's surviving nonexporters and newly-created firms. These are the export *starters*. The second term measures the flow out of exporting by last year's surviving exporters, the export *stoppers*. The export starter and stopper rates are γ^{starter} and γ^{stopper}. In a steady state, the flow into and out of exporting must balance, but in a transition, they need not. In panel B of Table 1, we report the starter and stopper rates from the U.S. and Colombian data.

Table 2: The extensive margin

	Export status$_t$			
	(1)	(2)	(3)	(4)
log sales$_t$	0.129***	0.053***	0.053***	0.043***
	(0.007)	(0.003)	(0.003)	(0.004)
exporter$_{t-1}$		0.640***	0.593***	0.636***
		(0.012)	(0.011)	(0.012)
exs$_{t-1}$			0.217***	0.220***
			(0.021)	(0.020)
N	76,662	76,662	76,662	76,662
adj. R^2	0.330	0.618	0.622	0.610

The sample covers 2008–2017. Columns 1–3 include industry and year fixed effects. Column 4 includes year fixed effects. Standard errors, clustered at the industry level, are reported in parenthesis. $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$.

Fact #1. Past export participation is the main predictor of current export participation.

In Table 2, we report the coefficients of a linear probability model whose dependent variable is one if the firm exports in period t and zero otherwise. Consistent with the exporter premium, larger firms are more likely to export. Column two adds lagged export status to the model, and the fit is greatly improved. A firm that exported last year is likely to continue exporting, although the coefficient on lagged export status is significantly less than one (Roberts and Tybout, 1997). The lagged export-sales ratio is also a significant predictor of export status, but adds little explanatory power to the regression. Comparing the models, size is a much less important predictor of export status once we control for a firm's export history. In the last column we remove the industry fixed effects and find these were adding very little explanatory power, suggesting it is primarily a proxy for export experience and size.

The importance of past export experience leads us to separately study the entry decisions of nonexporters and exit decisions of exporters. Beyond export participation, we also study additional aspects of a firm's export experience, such as previous export volumes or time since export entry or exit.

Fact #2. Exporter exit rates fall with past export intensity and time in the export market.

The first two columns of Table 3 report the coefficients of a linear probability model of export exit. In column one, we see that firms with larger export volumes (and not larger sales) and more experience exporting are less likely to exit the export market. If the firm entered the export market in the preceding period, the probability of exiting increases by 24 percent, even after controlling for the scale of its exports. It is not uncommon to observe a firm export for one period and then exit the market, even if it exported a large quantity in that sole year. The probability of exiting is falling with experience. The exit rate data suggest that export markets are difficult to crack for new exporters, but, the firms that do survive the initial shakeout are more likely to continue in the export market compared with those with less experience.

Fact #3. The exporter entry rate is low but is increasing in size and past export activity.

Most nonexporters do not start exporting. In Colombia, the export starter rate ranges from two percent in the 1980s to five percent more recently (Table 1). Table 3 reports the results of a linear probability model of export entry. While size increases the probability that a nonexporter starts exporting, so does past export experience and export intensity. Previous export experience raises the probability of reentering the market by about 20 percent.

2.3 The intensive margin

The first three facts are about the binary export status of a firm: the extensive margin. Fact #4 characterizes the evolution of a firm's export intensity, conditional on exporting: the intensive margin. In the cross section, the distribution of export intensity across all firms features a large mass of firms at zero — the nonexporters — and a non-degenerate distribution over the remaining export-intensity levels.[5] Our focus is on the dynamic properties of export intensity.

[5]There is another mass of firms that only export. There is some debate as to whether this reflects different competitive forces at home and abroad (Lu, 2010) or policy decisions (Defever and Riaño, 2017).

Table 3: Exporter entry and exit

	Stopper$_t$		Starter$_t$		
	(1)	(2)	(3)	(4)	(5)
log sales$_{t-1}$	0.003		0.027***	0.028***	
	(0.003)		(0.003)	(0.003)	
log exports$_{t-1}$	–0.032***	–0.022***			
	(0.003)	(0.001)			
starter$_{t-1}$	0.244***	0.207***			
	(0.010)	(0.005)			
starter$_{t-2}$	0.119***	0.084***			
	(0.013)	(0.005)			
log destinations$_{t-1}$		–0.075***			0.004***
		(0.002)			(0.0001)
log months$_{t-1}$		–0.100***			
		(0.002)			
exporter$_{t-2}$			0.214***	0.185***	0.158***
			(0.009)	(0.011)	(0.002)
exs$_{t-2}$				0.211***	
				(0.054)	
Market	World	Country	World	World	Country
N	15,631	324,297	47,289	47,289	20,598,517
adj. R^2	0.157	0.319	0.109	0.111	0.036

Columns 1, 3, and 4 cover 2008–2017 and include industry and year fixed effects. Columns 2 and 5 cover 2006–2018 and include destination-year fixed effects. Standard errors, clustered at the industry level, are reported in parenthesis. $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$. destinations$_t$ is the number of destinations served by the firm and months$_t$ is the number of months that included a shipment by the firm in a year. The transaction data do not include non-exporters. We measure the entry rate into a destination in period t of firms that actively export to at least one market in $t-1$.

Fact #4. Export intensity rises with time in the export market.

We regress the export-sales ratio on the previous year's export-sales ratio and variables that describe the exporter's history in the export market,

$$exs_{it} = \alpha + \sum_{k=0}^{K} \rho_{-k}\, exs_{i,t-k} + \beta_1 d_{it}^{\text{starter}} + \beta_2 d_{it}^{\text{exporter}} + \sum_{k=0}^{K} \theta_k d_{i,k}^{\text{stopper}} + \mu d_{it}^{\text{start,stop}} + \varepsilon_{it}. \quad (4)$$

The coefficient ρ_{-k} measures the persistence of an exporter's export-sales ratio k years prior, and the d variables are indicators for an export starter, stopper, or a one-period lived "starter-stopper." This approach allows us to trace out export-intensity dynamics and construct a long-run measure for a firm that exports continually, $exs_{LR} = \alpha/(1 - \sum_{k=0}^{K} \rho_{-k})$.

Table 4: Export intensity

	Export-total-sales ratio$_t$			
	(1)	(2)	(3)	(4)
exporter$_t$	0.216***	0.242***	0.073***	0.240***
	(0.017)	(0.017)	(0.006)	(0.002)
starter$_t$		–0.093***	0.070***	–0.078***
		(0.009)	(0.007)	(0.004)
stopper$_{t+1}$		–0.087***	–0.028***	–0.097***
		(0.009)	(0.004)	(0.004)
starter$_t$,stopper$_{t+1}$		0.063***	0.012	0.045***
		(0.013)	(0.009)	(0.007)
exs$_{t-1}$			0.543***	
			(0.012)	
exs$_{t-2}$			0.190***	
			(0.010)	
stopper$_{t+2}$				–0.040***
				(0.003)
stopper$_{t+3}$				–0.028***
				(0.003)
N	60,668	60,668	60,668	37,072
Adj. R^2	0.358	0.378	0.692	0.381

The sample covers 2008–2017. Standard errors, clustered at the industry level, are reported in parenthesis, $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$.

We report the estimates of (4) in Table 4. The average export intensity is 21.6 percent (column 1). Column two shows that a starter that continues into the next period will export a smaller share of its total sales than a continuing exporter. This share is similar to that of an exiting exporter in the last year of its exporting spell. A firm with a one-year exporting spell will sell less than either of these other firms, about 12.5 percent.

The third column shows that export intensity is persistent, with the sum of the coefficients on lagged export intensity nearly 0.73. In the last column, we see that exiters have lower export intensity in the years before they leave the market. Using the point estimates from columns three and four, we can trace out the path of export intensity for a new exporter that continues in the market and an exporter as it moves out of the export market (Table 5). A new exporter increases its export intensity by about 50 percent over five years while a stopper reduces its export intensity by a similar amount.

Table 5: Exporter life cycle: The export-sales ratio

	1	2	3	4	5	6	7	Long run
Starter	14.3	15.1	18.2	20.1	21.7	22.9	23.9	27.4
	–7	–6	–5	–4	–3	–2	–1	
Stopper	22.1	23.2	21.8	19.5	18.8	19.1	16.9	

2.4 Decomposing the Intensive Margin

Much like splitting trade flows into an extensive and intensive margin, moving from firm-level data to transaction-level data allows us to decompose the intensive margin into a series of extensive margins in terms of destinations (Eaton et al., 2008; Lawless, 2009; Arkolakis, 2016) or shipments.[6] This approach helps identify the frictions that determine the expansion pattern of exporters within and across markets. It speaks directly to where, and at what level, export costs are incurred and to the structure of these costs across markets and time (Albornoz et al., 2012; Schmeiser, 2012; Morales et al., 2019). These finer decompositions

[6] Two additional margins studied are products (Lincoln and McCallum, 2018) and customers (Eaton et al., 2015; Monarch and Schmidt-Eisenlohr, 2018).

are useful to the extent that they provide a better understanding of the cost structure of firms and their influence on aggregate dynamics.[7]

2.4.1 Destinations

We use the Colombian transaction data to evaluate how exit and entry rates by destination depend on history (Albornoz et al., 2016) and how firms grow by expanding within and across destinations (Eaton et al., 2008). The richer panel structure of these data allows us to control for firm- and destination-specific shocks. In terms of stopper rates (fact #2), we find a similar role for history (Table 3, column 2). We also find that stopper rates are falling in the number of months a firm exported to a market and the number of other markets that the firm is serving. This may indicate that entry costs in a market depend on the firm's access to other markets or its export experience (Morales et al., 2019, Timoshenko, 2015). In terms of entry rates, we again find that past exporting in a particular market is a good predictor of entry into a market (Table 3, column 5).

In Table 6, we study the dynamics of export growth at the firm-destination and firm level. We find that a new exporter that exports for three years will grow nearly 25 percent from their first to second year, but this growth-rate premium disappears by year two. Those in their last year of exporting contract exports by almost 95 percent. Firms that sell to more destinations tend to grow more slowly while those with larger foreign sales grow faster. In column 2, we control for the change in the number of months with a shipment in a year and find this greatly reduces the growth rate premium (discount) in the first year (last year). In column 3, we aggregate the firm's exports across destinations and find a larger growth rate premium in the first year. In column 4, we control for the firm's expansion across destinations and the number of shipments within destinations. The smaller growth-rate premium is similar to the within-market premium. These features suggest that the findings in Table 4 represent both within-market gradual expansion and across-market expansion.

[7] One could imagine, for example, a data set that provided the color of a shipment's container. Differentiating between red and blue shipping containers would likely not yield new information about the cost structure of a firm and would not be a useful decomposition.

Table 6: Export growth rates

	Δ_t log export			
	(1)	(2)	(3)	(4)
starter_{t-1}	0.245***	0.039**	0.410***	0.068**
	(0.022)	(0.014)	(0.041)	(0.015)
stopper_{t+1}	–0.948***	–0.280***	–1.042***	–0.251***
	(0.025)	(0.014)	(0.054)	(0.027)
starter_{t-2}	–0.011	–0.021*		
	(0.014)	(0.010)		
log exports_{t-1}	–0.184***	–0.147***		
	(0.005)	(0.004)		
log $\text{destinations}_{t-1}$	–0.077***	–0.071***	0.070**	
	(0.009)	(0.007)	(0.019)	
log months_{t-1}	0.033***		0.071***	
	(0.007)		(0.009)	
log total exports_{t-1}	0.105***	0.077***	–0.135***	–0.089***
	(0.006)	(0.004)	(0.015)	(0.007)
Δ_t log months		1.034***		0.988***
		(0.012)		(0.033)
Δ_t log destinations				0.146***
				(0.018)
Market	Country	Country	World	World
N	131,282	131,282	50,192	50,192
adj. R^2	0.116	0.445	0.128	0.474

The sample covers 2006–2018. Columns 1 and 2 include country-year fixed effects and standard errors are clustered at the country-year level. Columns 3 and 4 include year fixed effects and standard errors are clustered at the year level. Standard errors are reported in parentheses. $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$.

2.4.2 Shipments

As we have seen, the frequency with which products are traded within a year is closely related to exporter exit and growth. Most studies, however, use annual data that mask significant within-year variation. Higher-frequency trade-flow data suggest frictions different than those emphasized in the papers using annual data (Alessandria et al., 2010a; Kropf and Sauré, 2014; Hornok and Koren, 2015; Békés et al., 2017; Blum et al., 2019). The unit of observation in these data is usually an individual shipment, or the sum of shipments within a month, to a destination or customer.

Fact #5: Most firms import or export a few times per year. Shipment size increases, and frequency decreases, in distance. Trade grows through more frequent and larger shipments.

For example, Hornok and Koren (2015) find that the median U.S. and Spanish product is only shipped twice per year to a destination.[8] Many products are shipped only once per year, or even less frequently. This phenomenon is common to nearly all goods, even goods with large annual trade flows. The long gaps between shipments suggest that some continuous trading relationships may appear to stop and start when studied with annual data.

The frequency and size of transactions differ by destination. For a select set of goods, Alessandria et al. (2010a) find that, compared with international transactions, domestic transactions are smaller and more frequent. Several papers emphasize that shipment frequency falls and shipment size rises as distance increases (Hornok and Koren, 2015; Blum et al., 2019). The rise in trade through more frequent and larger shipments holds at both the firm and destination levels. Larger exporters to a market make both more frequent and larger shipments (columns 2 and 4 of Table 6). Likewise, when considering markets with more trade, we observe more frequent and larger shipments.

Fact #6: Firms hold larger inventories of goods from, or destined for, foreign markets.

The discreteness of shipments can be explained by either discrete demand or discrete purchases. Inventory data are useful in determining the sources of discreteness. Discrete

[8]The U.S. product is measured at the 10-digit Harmonized System (HS) level and the Spanish product is at the 8-digit HS level.

purchases imply that importers must hold larger stocks of these inputs relative to their usage or exporters must hold larger stocks of their finished goods relative to their sales. Studies find that inventories of imported inputs are two to three times those of domestic inputs (Alessandria et al., 2010a; Nadais, 2017). On average, firms will hold 2–3 months of domestic inputs in inventory compared with 4–6 months of imported inputs.

2.5 Cumulative effects of firm dynamics

The relatively small size, high exit rate, and slow growth of new exporters means that it takes time for export sales to be reallocated away from existing exporters. The cumulative effects of the firm-level dynamics can be seen in Table 7. The columns labeled *entrants' share* report, at different horizons, the share of all firms (panel A) or total exports (panel B) accounted for by firms that did not export at the beginning of the sample. For example, 20 percent of all exporters did not export one year prior and that share grows to 36 percent after five years. These new exporters account almost 11 percent of exports in year one and this rises to 21 percent after five years. With transaction-level data, we find that new exporter-destinations are more common: In one year, 40-percent of all firm-destinations are new. The churning in the number of firms has a modest impact on export volumes. After five years, new exporters account for 21 percent of total exports.

2.6 Aggregate dynamics

Models that address firm dynamics have proven useful in understanding aggregate trade dynamics, measured either as net exports' share of trade or the trade share of expenditures, following shocks to trade barriers or to business cycles conditions. Generally, net and gross trade flows respond gradually following these aggregate shocks, although sometimes trade moves sharply, such as in the Great Recession (Bems et al., 2013).

Fact #7: The long-run response of aggregate trade volumes to changes in trade policy is larger than the short-run response.[9]

[9] Our focus is on the trade elasticity at different time horizons following a change in trade policy. This is conceptually distinct from the idea that elasticities may depend on the level of trade (Head et al., 2014).

Table 7: Aggregate effects of entry, exit, and growth

	continuation rate				entrants' share		
Window (months)	1	6	12	36	12	36	60
Panel A: Number							
Firm			80	76	20	30	36
Firm, balanced			85	83	15	21	24
Firm*	64	65	59	41	41	54	63
Firm-destination*	54	63	60	46	40	54	62
Panel B: Export value							
Firm			89	91	11	18	21
Firm, balanced			94	98	6	8	7
Firm*	95	98	98	96	2	7	11
Firm-destination*	85	95	94	92	6	13	19

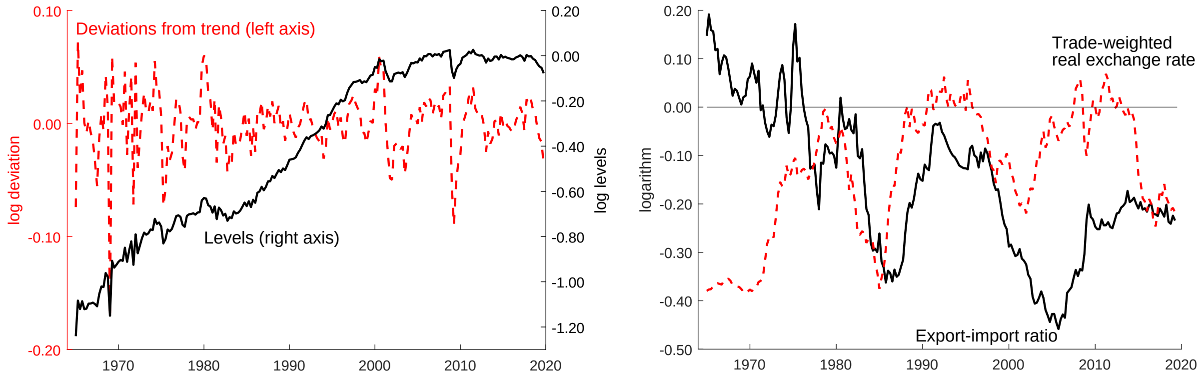
The sample covers 2006–2018. Panel A: *Continuation rate* is the share of exporters that remain exporters across two windows, e.g., 80 percent of firms who exported in a 12-month window export in the next 12-month window. *Entrant's share* is the share of total exporters accounted for by entrants, e.g., 30 percent of exporters are firms that did not export 36 months prior. Panel B: The columns are defined analogously but for export volumes, rather than firm counts. *From the customs transaction-level data.

After controlling for the "phase-out" implementation of free trade agreements (FTAs), Baier and Bergstrand (2007) find that trade growth is split equally over the first 10–15 years of the FTA and growth continues at longer horizons (Jung, 2012). Figure 1(a) shows this gradualness clearly in the U.S. data. It plots the growth in U.S. trade (exports plus imports of goods) relative to expenditures on goods.

A key source of the larger long-run response is the expansion in the extensive margin. At the product level, Kehoe and Ruhl (2013) find that nontraded products, or products traded very little before an FTA, grow faster than other goods following an FTA. They find that the relationship between extensive margin growth and aggregate trade growth is stronger at longer time horizons. Buono and Lalanne (2012) and Baier et al. (2014) reach similar conclusions. At the firm level, the gradual expansion at the extensive margin occurs through increased entry and reduced exit, as documented in Alessandria and Choi (2014a).

The gap between the short- and long-run trade elasticity may be even larger than that found in previous studies, as there are substantial anticipatory effects prior to a tariff reduction. Khan and Khederlarian (2019) find large decreases in trade leading up to the tariff

Figure 1: U.S. aggregate trade



(a) U.S. trade (exports plus imports)

(b) U.S. net trade and real exchange rate

cuts, followed by large increases in trade once the tariffs are cut. Compared to conventional estimates (e.g., Romalis, 2007), the one-year trade elasticity is 50 percent larger (2.8 versus 4.2) and the five-year trade elasticity is 10 percent larger (8.2 versus 9.0).

Most studies of open-economy business cycles consider the comovement of net trade flows with international relative prices, which we plot for the United States in Figure 1(b). The real exchange rate clearly leads net trade flows. The lagged response of trade to the depreciation of the dollar in the 1980s is what motivated Baldwin and Krugman (1989) and others to propose dynamic trade models. In U.S. data for 1980–2015, Alessandria and Choi (2019) find that the real exchange rate leads net trade flows by about eight quarters. They find a short-run price elasticity of trade of 0.20 and a long-run elasticity of 1.2, with only six percent of the gap between the short-run and long-run response closed per quarter.

Despite the consensus that trade responds slowly to aggregate shocks, there are examples where the adjustment is very fast. In the Great Recession, for example, international trade fell about 50 percent more than expenditure on traded goods and rebounded sharply, even as expenditure on traded goods rebounded by less. Figure 1(a), which plots the deviations from trend for trade (exports plus imports of goods) as a share of expenditure on goods, shows these sharp decreases and increases clearly. Boileau (1999) finds that total trade is cyclical because it is intensive in durable goods, however, the high elasticity of trade to expenditure exists, even when one controls carefully for the composition of expenditures. Alessandria et al. (2010b), for example, show that U.S. imports of Japanese autos fell and rebounded much more sharply than U.S. sales of Japanese autos in the Great Recession.

The time-varying slow and fast responses of trade to shocks present an enormous challenge to static models. When the trade data are interpreted through the lens of a static trade model, such as the gravity model, gradual and sharp adjustments — above and beyond those captured by changes in expenditures or relative prices — are captured in the error term that is treated as an additional shock to trade barriers. Dynamic models provide some structure for these shocks, and are naturally able to generate the adjustments observed in the data. We turn to these models next.

3 Firm decision problems

We lay out the canonical dynamic model of exporting used to address the facts introduced above (Das et al., 2007). We start with the firm's decision problem and move to general equilibrium in section 4. Consider a firm i that already sells to the domestic market and is contemplating exporting. Let x_{it} be equal to one if the firm exports in t and zero otherwise. The flow profit is $\pi\left(x_{it}, z_{it}, d_{it}\right)$, where z_{it} captures variables related to production efficiency and d_{it} is demand for firm i's product in the foreign market. Export fixed costs, $f_{it}(x_{it-1}, \epsilon_t)$, depend on the firm's past export participation and a random variable. These three factors — demand, production costs, and fixed export costs — are meant to be very general and we will discuss later how different mechanisms considered in the literature are captured by these factors.

A firm's foreign demand depends on factors that are common to all firms (the size of the foreign market, the real exchange rate) and ones that are idiosyncratic to the firm or the firm-destination pair (idiosyncratic demand shifters, shipping and distribution technologies and capital). Demand for the firm charging price p is often written as

$$d_{it}(p_{it}) = \omega_{it} \left(p_{it} \frac{\tau_t^* \widetilde{\xi_{it}}}{P_t^*} \right)^{-\theta} D_t^*, \tag{5}$$

where P^* is the price of a composite industry or final good, D^* is total spending, $\tau^* \geq 1$ is an ad-valorem tax paid by foreign consumers, ω is a firm-specific demand shifter, and $\widetilde{\xi} \geq 1$ is a firm-specific iceberg trade cost. We denote foreign variables with an asterisk. A firm will not export if foreign demand is equal to zero or if the shipping cost is infinite.[10] In practice, the two firm-specific shifters, ω and $\widetilde{\xi}$, are redundant as they affect total sales identically; we combine the two into $\xi_{jt} \in [0, \infty)$ and refer to the composite variable as an "iceberg" export cost. This cost is stochastic and follows an AR(1) process.

Firms operate a constant returns to scale technology. The production cost term, z, captures supply-side determinants of a firm's profit, including total factor productivity, physical capital, and intangible assets. Productivity has been a major focus of the literature. Empirically, firms that export tend to have higher measured productivity levels and the heterogeneous-productivity model in Melitz (2003) is a workhorse in the field. It is common to assume that productivity follows an AR(1) process.

Firms make an investment in foreign market access. Baldwin and Krugman (1989) modeled this investment as a fixed cost, and much of the literature has followed suit. The fixed cost is $f = f_0$ when $x_{t-1} = 0$ and $x_t = 1$ and $f = f_1$ when $x_{t-1} = 1$ and $x_t = 1$. When $f_0 > f_1$ we say that the difference between the two, $f_0 - f_1$, is the *sunk entry cost*. When fixed trade costs only depend on last period's export status, including export history in a firm's state is redundant; however, with a richer model where experience wears off slowly or is accumulated, one may need to keep track of that history to determine the evolution of other firm states.

The firm's state variables are (z, ξ, f) and the value of the firm is

$$V_t\left(z_{it}, \xi_{it}, f_{it}\right) = \max\left\{V_t^0\left(z_{it}, \xi_{it}, f_{it}\right), V_t^1\left(z_{it}, \xi_{it}, f_{it}\right)\right\}, \tag{6}$$

where the value of not exporting and only selling domestically is

$$V_t^0\left(z_{it}, \xi_{it}, f_{it}\right) = \pi_t\left(0, z_{it}, \xi_{it}\right) + \delta_{it} \mathop{\mathbb{E}}_{z,\xi,f} \frac{1}{1 + r_{t+1}} V_{t+1}\left(z_{it+1}, \xi_{it+1}, f_{it+1}\right) \tag{7}$$

[10] While CES demand requires an infinite variable cost to drive demand to zero, other models have a reservation price at which demand falls to zero. See Arkolakis et al. (2018a) for a description of a class of demand functions with this property.

and the value of exporting is

$$V_t^1(z_{it},\xi_{it},f_{it}) = \pi_t(1,z_{it},\xi_{it}) - f_{it}(x_{i,t-1},\epsilon_t) \\ + \delta_{it} \mathop{\mathbb{E}}_{z,\xi,f} \frac{1}{1+r_{t+1}} V_{t+1}(z_{it+1},\xi_{it+1},f_{it+1}), \tag{8}$$

where r is the interest rate and δ is the probability that the firm survives to $t+1$. Notice that the value functions are functions of t. This most general case will be appropriate when we consider transitions in general equilibrium settings. The partial equilibrium models are almost always considered in stationary environments, so we drop the t subscript for now and use the "prime" notation common in the stationary dynamic programming approach.

3.1 Decision rules

To simplify the exposition, we assume that f is deterministic. We also assume that profit functions are increasing in z and that the incremental profit from exporting, compared with selling only in the domestic market, is increasing in z. A common assumption that generates this feature is that the firm is a monopolistic competitor producing a differentiated good and z measures productivity, as in Melitz (2003).

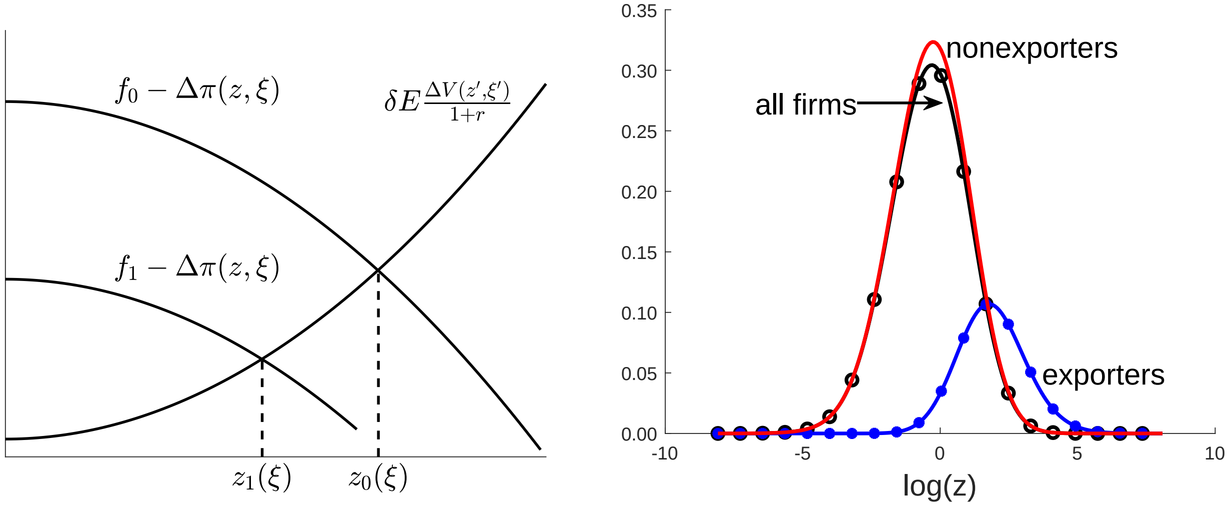
Under these assumptions, the policy function for exporting is a cutoff rule that depends on the fixed cost, which depends on export history. For each ξ there exists a $z_m(\xi)$ such that a firm with variable export cost ξ and $z \geq z_m(\xi)$ will export. This cutoff technology level is determined by

$$f_m - [\pi(1,z_m(\xi),\xi) - \pi(0,z_m(\xi),\xi)] = \frac{\delta}{1+r} \mathop{\mathbb{E}}_{z',\xi'} \left[V^1(z',\xi',f_1) - V^0(z',\xi',f_0)\right]. \tag{9}$$

The left-hand side of (9) is the net cost of exporting: The export cost minus the extra profit today from exporting. The right-hand side of (9) is the increase in the expected value of the firm if it chooses to export, what we call the *future benefit* from exporting. The left- and right-hand sides of this break-even condition are plotted in Figure 2(a) for $f_0 > f_1$.

In the *sunk-cost model*, $f_1 < f_0$ and $z_1(\xi) < z_0(\xi)$. All else equal, it takes a more profitable firm to enter than it does to remain in the market. In the *fixed-cost model*, $f_0 = f_1$

Figure 2: Model properties



(a) Entry and exit thresholds

(b) Firm distributions

and the right-hand side of (9) is zero so that the firm chooses to export whenever the current extra profit from exporting exceeds the fixed cost. This generates a static export decision, and a single productivity threshold $z_1(\xi) = z_0(\xi)$.

The shape of the future benefit curve in Figure 2(a) is governed by two forces. The slope is largely determined by the persistence of the productivity process: A more persistent z implies a steeper slope. The level of the future benefit curve is driven by the size of the sunk cost, $f_0 - f_1$. When $f_0 = f_1$, the future benefit curve is identically zero. If we hold f_1 constant and increase f_0, the future benefit curve shifts up and z_1 falls. Firms want to avoid paying f_0 again in the future, and may even earn negative profits in a period $(\pi - f_1 < 0)$ to retain the positive future value of continuing in the export market. As we increase f_0, we also increase the cost of entering the export market (the $f_0 - \pi(z)$ curve shifts out) so that z_0 increases. Intuitively, with a larger sunk cost of exporting, there is a larger productivity gap between firms that have and have not paid it.

The threshold productivity levels are important determinants of the exporter premium in (1). Holding fixed the firm-size distribution, when the thresholds are farther apart, there is more scope for smaller exporters and larger nonexporters. This tends to decrease the exporter premium. As the distance between the thresholds shrinks, sorting by productivity into exporting is stricter and the export premium rises. The exporter premium is one of the key empirical moments that discipline the model's parameters.

3.2 Firm distributions

The cutoff thresholds and the processes for z and ξ determine the distribution of firms over fixed cost, productivity, and demand levels, which we denote $\mu(z, \xi, f)$. The distribution over nonexporters is $\mu(z, \xi, f_0)$ and $\mu(z, \xi, f_1)$ is the distribution of exporters. These distributions allow us to aggregate firm-level decisions and determine the starter and stopper rates.

In Figure 2(b), we plot the beginning-of-period distributions of firm productivity for a given shipping-cost/demand (ξ_t) realization. The distributions of exporters and nonexporters overlap when $f_0 > f_1$. If $f_0 = f_1$, the two distributions would be disjoint, which is counterfactual. While the average exporter is larger and more productive than the average nonexporter in the data, the smallest exporter is much smaller than the largest nonexporter. In the range $[z_1(\xi), z_0(\xi)]$ in the sunk-cost model, there can be firms with the same type z who both export and do not export. In this interval, a firm's export status depends on whether it has paid f_0 in the past.

3.3 Dynamic properties

The dynamic properties of the sunk-cost model help us understand several features of the data that would otherwise be difficult to explain.

Hysteresis. The sunk-cost model generates exporter hysteresis: An exporter will continue to export even after its current conditions have worsened relative to the conditions it faced when it started exporting. Holding its demand shifter constant, a firm will continue to export even if its productivity has fallen below the entry threshold — it will continue to export as long as productivity is above $z_1(\xi)$.[11]

The different thresholds that generate hysteresis can also help explain the low exit and entry rates. With a persistent process for z, the probability that a marginal starter exits the

[11] This idea was originally formulated in terms of the aggregate shocks from a real exchange rate change but applies equally to idiosyncratic shocks.

export market depends on the probability that the firm receives a shock that takes it from z_0 to z_1, which, holding the thresholds constant, is falling in the shock's persistence and rising in the shock's variance. The key to identifying the entry (f_0) and continuation (f_1) costs is the relatively low exporter premium and the relatively high persistence of export participation, since these features only arise with a large gap in the entry and exit thresholds.

Current and future trade costs. The forward-looking problem that firms solve when $f_0 > f_1$ implies that future, as well as current, changes in export profitability matter for the export entry decision. Policy-related costs, such as tariffs and nontariff barriers, are particularly interesting in this context because they are often phased in over several years following the signing of a trade agreement.

First, consider a decrease in ξ in the current period that permanently reverts in the next period to its previous level. This decreases the left-hand side of (9) and leaves the right-hand side unchanged. This is equivalent to shifting the downward-sloping curves in Figure 2(a) down and both the entry and exit thresholds shift down. How much the thresholds change depends on the size of the change in trade costs and the elasticity of profits with respect to trade costs. This temporary shock persistently increases trade through increased entry and reduced exit.

Second, consider a decrease in future trade costs that holds current trade costs fixed — an announcement that a trade deal has been signed and will come into force in the future. The left-hand side of (9) stays constant, but the right-hand side increases.[12] This is equivalent to shifting the upward-sloping curve up in Figure 2(a) and lowers both the entry and exit thresholds, increasing the number of exporters and the volume of exports today. The reaction to a change in trade costs will depend on the persistence of the change. Holding fixed the size of the change, the more persistent is the change, the larger is the increase in the future value of exporting. A one-period change has a very small effect on the future value of exporting; A permanent change will have the largest effect. Thus, the current response to a unobserved future change in trade barriers can be used to identify the expected path of future policy.

[12] We have written (9) in the stationary steady state: There are no time subscripts on the value functions. Changing future trade costs will change the value functions. For brevity, we do not rewrite the break-even condition for this case.

Finally, consider a surprise permanent cut in the current and future trade costs. This will have a larger effect on the thresholds as it combines the previous two experiments.

Uncertainty. As in other applications of sunk-cost models, uncertainty creates an incentive to delay a costly action such as changing export status (Dixit and Pindyck, 1994). This leads nonexporters to delay starting to export and exporters to delay stopping to export. An increase in uncertainty is reflected in Figure 2(a) as a shift up and flattening of the upward-sloping curve, increasing the band of inaction, $[z_0(\xi), z_1(\xi)]$. This movement increases the threshold for entering the export market but also lowers the threshold for exiting the market. With both margins changing, the net effect on export participation and aggregate trade is ambiguous, even though it is commonly stated that uncertainty reduces trade.

3.4 Successes and challenges in the model

The canonical model from section 3 can generate several of the facts that we document in section 2. The model generates persistent export participation (fact #1) and low export entry and exit rates (facts #2 and #3). The dynamic adjustment to shocks is slow, generating an elasticity with respect to the shock that is larger in the long-run than the short-run (fact #7). Despite these successes, the model misses on some important aspects of the data. We consider the following four features since they speak directly to the timing and size of the investments that firms make in market access.

Conditional exit rates. A new exporter is one that received a positive innovation to z, crossed over the entry threshold, and is far from the exit threshold. The persistence of z implies that the entrant should not move to the exit threshold soon: An export entrant has a low probability of exiting and, as z reverts to its mean, the exit rate increases with time in the export market. In the data, however, we find the opposite: The exit rate falls with time in the export market (fact #2), even when we control for other characteristics such as export volume.

New exporter size and export intensity dynamics. Export starters are too large compared with those in the data. The large f_0 in the model generates too much selection on firm size. The export-sales ratio is a function of ξ. If ξ is constant, so that paying f_0 instantly lowers ξ from a prohibitive level to its final value, then the export-sales ratio counterfactually jumps up on entry and displays no growth afterward. In the data (Table 4), the export-sales ratio of a new exporter starts low and grows over several years (fact #4).

Destination churning and reentry. Models with destination-specific sunk costs can capture the high persistence in destination-specific participation, but it is not clear why participating in multiple markets decreases the probability of exit. A key challenge is that dynamic models of these destination-specific investments are not well-developed.

When a firm exits the export market, it must pay f_0 again to export in the future. This makes it rare to observe a firm exiting the export market and reentering soon after. In the data, we find the opposite to be true. In Table 3, we see that a firm is more likely to enter the export market if it exported two years prior (fact #3). When we consider the high-frequency data, we see that many firms take short breaks from the export market within a year (fact #5). Recall from Table 7, that the continuation rate of exporting in monthly data is lower than in longer-horizon data.

High short-run elasticity. The high-persistence of firm-level exporting means that the canonical model cannot generate the sharp changes in export volumes that we occasionally observe (Figure 1).

3.5 Resolutions

The stark specification of the technology that governs foreign-market access drives the model's key failings. The upfront investment in market access (f_0) instantly lowers, with certainty, the marginal cost of exporting (ξ) and the cost of retaining market access (f_1). Exiting the market for one period fully depreciates this investment. Generating the observed firm-level behavior in the data requires shifting more of the investment in market access to the periods following entry and allowing this investment to depreciate slowly.

Consider a richer fixed cost structure in which: 1) a firm that stops exporting can pay $f_R < f_0$ to reenter the market, but a firm that has never exported must still pay f_0; and 2) the continuation costs, $f_1(t_e)$, fall with time in the export market, t_e. The smaller "reentry cost" leads firms to temporarily leave the market when export demand is low and come back when it is higher, accounting for the reentry in the data. The reentry cost specification implies that, compared to the simple model, market access depreciates more slowly, which tends to increase the estimated initial investment in market access, f_0. A gradually falling continuation cost decreases the probability that a firm exits as it gains experience in the market, accounting for the conditional exit rates in the data. This specification of the continuation cost increases future market access costs, which tends to decrease the estimated f_0. If the net result of these two forces is a decrease in f_0, then smaller non-exporters will enter the export market, as in the data.

If $f_0 = f_1$ and the firm's good can be stored with a cost, firms in the canonical model will order infrequently and hold inventories. This parameterization of the model will account for fact #5. This setup will also generate a large short-run elasticity. For example, when tariffs are cut, export volumes grow quickly because firms can use their inventories to immediately meet increased demand.

Changing the fixed cost structure cannot address the observed export-intensity that rises with time in the market. One approach is to modify the iceberg-cost technology to allow the cost to fall with export experience. Alessandria et al. (2014), for example, assume new exporters start with an inefficient shipping technology ξ_H that stochastically falls to $\xi_L < \xi_H$, as would be the case with a firm building a better foreign distribution and sales network. Alternatively, demand could grow with experience in the export market from the accumulation of customers or habit (Fitzgerald et al., 2016; Piveteau, 2016; Ruhl and Willis, 2017; Rodrigue and Tan, 2019). Both approaches imply that the costs incurred to continue in the export market when young include an investment in better future market access. These extensions generate paths of rising sales and profits. When profits are more backloaded than in the sunk cost model, the entry cost is estimated to be lower. The smaller entry cost, again, leads to smaller new exporters and higher exit rates by new exporters.

When we turn to our general equilibrium analysis, we will consider two versions of the canonical model. The first model assumes that firms pay a cost to export that gradually and stochastically leads to a falling iceberg cost and call it the *export-investment* model. This model captures a firm's export life cycle but does not distinguish exporter dynamics within destinations and across destinations. The second model assumes all firms are exporters but must decide when to export subject to a fixed shipment cost and a holding cost on unsold stocks held abroad. We call this the *inventory* model.

3.6 Extensions

A growing literature has built on the sunk-cost model by incorporating additional frictions and opportunities that affect firm dynamics in an open economy.

In general, input adjustment frictions affect the export participation decision and a firm's overall growth, but have no impact on export intensity dynamics, because they affect the cost of producing for the domestic and export market symmetrically. Alessandria and Choi (2007), Riaño (2011), Rho and Rodrigue (2015), and Rho and Rodrigue (2016) introduce physical capital adjustment in the form of convex and nonconvex costs of adjustment and time to build. These frictions create decreasing returns to scale in production that reduce the benefits of export expansion. The growing literature on trade policy in the presence of labor market frictions has largely abstracted from dynamic export decisions. Coşar et al. (2016) develop such a model to study how job turnover and unemployment change with trade integration in Colombia. Fajgelbaum (2020) studies how the timing of export entry in a firm's life cycle is affected by labor frictions.

In the data, firms that export are often firms that import. Kasahara and Lapham (2013) study the link between sunk costs of importing and exporting, and estimate a strong complementarity between the two. Several papers treat the import decision as subject to sunk costs and irreversibilities (Lu et al., 2016; Ramanarayanan, 2017; Imura, 2019) and find that these frictions are large and severely inhibit the adjustment of trade flows.

The contribution of export participation to firm-level productivity has been hotly debated. Most work argues for selection in export participation, although some evidence for learning from exporting exists. More recent work has focused on the link between R&D and firm-level productivity. Aw et al. (2011) estimate a dynamic, structural model of exporting and productivity-enhancing R&D. They find a complementarity between exporting and R&D activities—both of which are undertaken by relatively high-productivity firms. Starting with

Atkeson and Burstein (2010), several papers explore the interaction between innovation and trade in models of firm dynamics that focus on trade's role in aggregate growth.[13]

Recent work has studied the impact of financial conditions on export outcomes. In general, financial constraints delay export participation, but this finding depends on the structure of the constraint (Brooks and Dovis, 2019). Kohn et al. (2016) introduce working capital constraints into a sunk-cost model and, motivated by data, assume that the constraint is tighter on a firm's export operations. Since export markets are more constrained than domestic markets, export-intensity grows more slowly than in the sunk-cost model. Caggese and Cuñat (2013) show that financing constraints reduce the productivity gains from trade liberalization, as productive firms cannot borrow to finance exporting costs. Leibovici (2018) shows that cross-country differences in financial development determine comparative advantage with minimal effects on overall trade flows.

In the canonical model, firms are uncertain about the future, while knowing the current state. Following Jovanovic (1982), several papers have introduced uncertainty and learning to explore the pattern of expansion within markets (Eaton et al., 2014; Timoshenko, 2015; Cebreros, 2016; Arkolakis et al., 2018b) and across markets (Albornoz et al., 2012; Schmeiser, 2012). Within a market, uncertainty about demand leads firms to start small. If sales come in strong, firms update their beliefs and make larger shipments. Across markets, firms learn about the fixed costs of making foreign sales. As firms update their beliefs over their fixed costs of exporting, they enter into markets where they expect the fixed costs to be lowest.

4 Aggregate dynamics

In models with firm dynamics, the aggregate response to a shock differs substantially from that in static models. We study two extensions of the canonical model that differ in their sources of exporter dynamics and operate at different frequencies: the export-investment model and the inventory model. Unlike static trade models, which generate nearly linear relationships between tariffs, trade flows, and consumption, these dynamic models generate

[13]See Alvarez et al. (2013), Perla et al. (2015), and Sampson (2016). Baldwin and Robert-Nicoud (2008) discuss many of the ways that trade affects growth in heterogeneous-firm models.

highly non-linear, and sometimes perverse, relationships between these variables.

The two models share the same general structure. The economy is made up of two countries in general equilibrium. Firms produce differentiated varieties and a representative firm aggregates domestic and imported varieties to create a final non-traded good. The elasticity of substitution between varieties is the demand elasticity faced by firms. To the firms' problems, we add household optimization, market clearing conditions, and laws-of-motion over firm distributions. With symmetric countries and policies, trade is balanced regardless of the financial assets available.[14] The complete details of the models are reported in the online appendix. We consider the effect of a once-and-for-all, global, unanticipated elimination of a ten-percent tariff. While surprise once-and-for all global tariff cuts are rare, they cleanly separate the impact and lagged effect of a policy reform in the model.

4.1 Aggregate effects in export-investment models

In section 3, we described a variety of frictions that make exporting a dynamic decision. Here, we consider a variation of the sunk export-cost model that allows the exporter's variable trade cost to fall with export experience. Alessandria et al. (2013) show that this model closely matches the size, survival, and export intensity dynamics of exporters in the data. In the online appendix, we consider alternative models. Besides the export technology, we add free entry of firms. A new firm is created by paying f_e units of labor, after which, its initial productivity is realized. A free-entry condition, as in Hopenhayn (1992), equates the expected value of entry with the entry cost. Firms face idiosyncratic productivity and survival shocks. Production requires physical capital, labor, and intermediate inputs. To highlight the implications of modeling trade dynamics, we compare the outcomes from the dynamic model to a static one in which all firms export with a single variable export cost.

The key dynamic feature is the overshooting of consumption in the transition, with consumption substantially above its long-run level 25 years after the tariff cut (Figure 3(a)). This arises because the cut in tariffs leads to a drop in firm creation (Figure 3(d)), which frees

[14] Recent work emphasizes that the response to a change in trade barriers depends on the financial assets available. See, for example, Alessandria et al. (2014); Reyes-Heroles (2015); Alessandria and Choi (2019); Eaton et al. (2016); Alessandria et al. (2017); Brooks and Pujolas (2018); Ravikumar et al. (2019).

resources up along the transition and lowers the number of firms in the new steady state. The drop in firm creation arises because the time and costs of exporting lead potential entrants to strongly discount export profits and mostly consider domestic profits that are negatively affected by the increased foreign competition. The slowly evolving structure of the firm distribution drives the slow transition in consumption.

The transition paths in the two models are radically different, resulting in different relationships between welfare and steady-state consumption (Table 8). In the static model, the welfare change is 77 percent of the steady-state consumption change. The economy accumulates capital to reach its new steady state, even as the trade share jumps to its new level. In the dynamic model, the welfare change is almost 10.4 times the change in steady-state consumption. Comparing steady states in the static model is somewhat informative of welfare gains—in the dynamic model it is not.

Trade also behaves very differently across the two models. In the static model, the long-run trade elasticity is four, which is the parametric elasticity in the function that aggregates varieties. In the dynamic model, this elasticity is more than twice as large, even though the elasticity of substitution in the aggregator is the same as that in the static model. This is the result of an increase in exporters (extensive margin) and investments that lower average export variable costs (intensive margin). Lower tariffs induce firms to stay in the export market longer, increasing the possibility of acquiring a lower variable export cost. The larger increase in trade takes time to develop, as is evident in Figure 3(b).

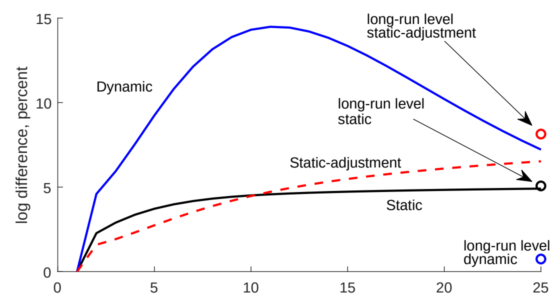
Comparing the static and dynamic models, we see that the paths of aggregate trade differ substantially. To better understand the implications of aggregate trade dynamics, we recalibrate the static model so that its aggregate trade path following trade reform matches exactly that in the dynamic model. To do so, we increase the elasticity of substitution (θ) to match the long-run growth in trade in the dynamic model and we add an adjustment friction on aggregate trade to match the transition path of aggregate exports in the dynamic model. The report the results from this model in the third column of Table 8. While this alternative model generates a larger increase in steady-state consumption and welfare, the path of consumption is quite different from the dynamic model, suggesting that one should be cautious of using static models to measure the aggregate effects of changes in trade policy.

Table 8: Results from a tariff cut

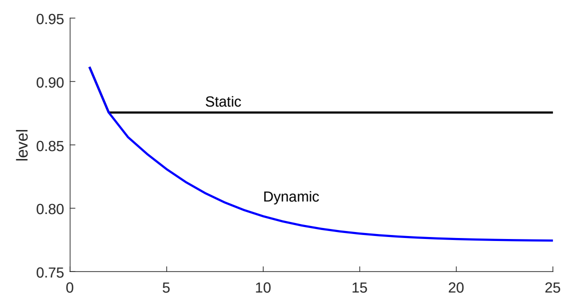
	Static exporters	Dynamic exporters	Static: Adjustment costs
Long-run trade elast.	4.00	11.55	11.55
ΔC_{ss}	5.18	0.75	8.14
Δ Welfare	3.91	7.78	5.61
Δ Welfare/ΔC_{ss}	0.77	10.44	0.69

Figure 3: Effect of a reduction in tariffs

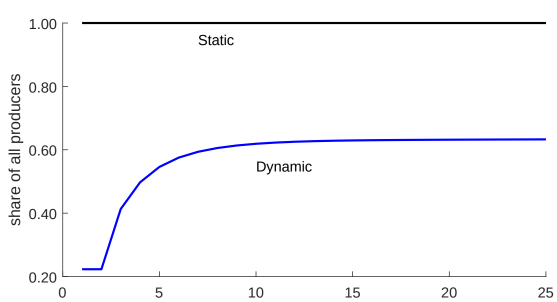
(a) Consumption



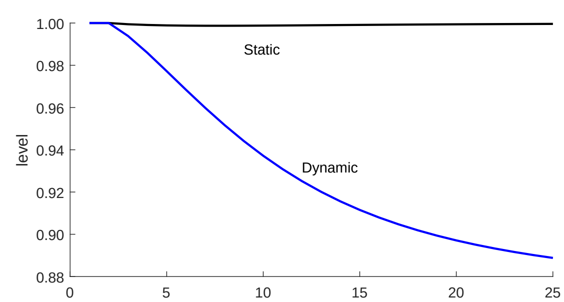
(b) Domestic expenditure share



(c) Share of firms that export



(d) Firms



4.2 Factors influencing aggregate results

The dynamics of consumption and trade following a tariff cut will depend on a wide range of features related to firm dynamics, preferences, accumulable factors, trade policy dynamics, and country characteristics. In terms of firm dynamics, we generally find that any of the mechanisms that involve an investment in market access that make exporting a dynamic decision will lead to slow transitions and overshooting in consumption and output, provided firm entry is endogenous. For preferences, the amount of overshooting is usually increasing in the Intertemporal Elasticity of Substitution (IES) and the interest rate. The IES does not affect the long-run impact of a cut in tariffs, but the consumption response is generally falling in the interest rate. The interest rate, which is determined by the consumer's discount factor, determines the weight of uncertain, future export opportunities in the value of firm entry. Alessandria et al. (2014) show that when $r = 0$, the Arkolakis et al. (2012) formula for the change in steady-state consumption given a marginal change in trade costs, holds. Given the drawn out transitional dynamics, however, the steady-state change in consumption is a poor approximation for consumption early in the transition, and this approximation worsens as the interest rate increases.

Many of the results on trade and aggregate transitions we describe apply to experiments with global tariff declines in symmetric countries, but there are some results in other cases. Unilateral reforms generate smaller gains for the reforming country but also feature overshooting so that the welfare gains may actually have a different sign from static trade models. Recently, Mix (2019) shows that the welfare gains of global reforms in multi-country models with rich geography are well approximated by two-country symmetric models, although the transitions and long-run effects are shaped by geography and country size.

The transitional dynamics will depend on the presence of capital and whether trade is capital-intensive, the precise structure of fixed costs, and industry heterogeneity. When trade is capital-intensive, a source of the welfare gains from trade is lower capital prices, which generate capital deepening. With slow trade dynamics, this dampens overshooting and raises the long-run growth in the economy. With heterogeneous industries, comparative advantage forces offer an additional source of gains boosting long-run effects. Finally, when fixed costs are denominated in goods, rather than in labor, which is necessary for a stable firm size distribution, the model features more-neoclassical transitions and larger welfare gains.

4.3 Aggregate effects in inventory models

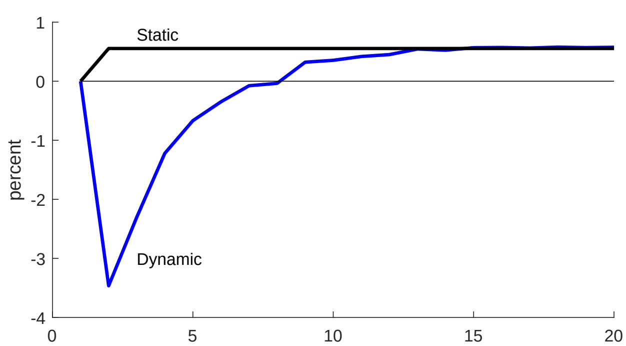
The slow transitions in the export-investment model are at odds with the sharp collapse and rebound of trade common to recessions and their recoveries. The canonical dynamic model can easily incorporate frictions to generate these large movements in trade. Suppose that exporters sell y units from a stock of goods z held in the foreign market, $z \geq y$, and these stocks are subject to a storage cost δ_z. Replenishing this stock with an export shipment, $x > 0$, incurs a fixed cost and the shipment arrives the next period. The law of motion is

$$z_{t+1} = (1 - \delta_z)(z_t - y_t) + x_t. \tag{10}$$

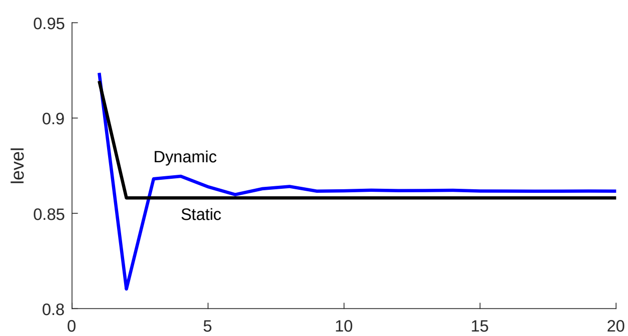
For simplicity, assume that firms have a common productivity, but face idiosyncratic demand shocks each period. The solution to this decision problem is a reorder threshold and reorder level. The reorder threshold is a function of realized demand and current inventory level. The shipment fixed cost, storage cost, and demand process are calibrated to match the frequency and size of shipments, which we summarized in section 2.4.2. There are similar, but smaller frictions for domestic transactions. The model period is a quarter. A complete description of the model is available in the online appendix.

We compare trade dynamics in the inventory model to a similar, but static, model with no shipment lags and full depreciation ($\delta_z = 1$). The static model is calibrated to match the same initial trade share as in the dynamic model. To highlight the novel features here, and separate them from the features in the export-investment model, we eliminate the free-entry decision for firm creation and consider a fixed set of firms. Production only uses labor.

Figure 4: Exporter inventory model



(a) Consumption



(b) Domestic expenditure share

In the first quarter following the tariff cuts, trade more than doubles, overshooting its long-run level. This drives the sharp decrease in the domestic expenditure share in Figure 4(b). After the initial surge, trade drops below its long-run level and non-monotonically converges to its long-run level. Surprisingly, even though trade rises on impact, consumption falls by 3.4 percent before gradually rising to nearly 0.6 percent above its initial level (Figure 4(a)). This is the result of firms shipping more to the foreign country (to build inventory levels), which requires paying fixed costs. On impact, a larger-than-long-run share of firms place orders, creating a short-run investment in market access. In the static model, trade immediately adjusts and consumption increases on impact. The transition's half life lasts about one year, which is much faster than the model in the previous section. The source of trade dynamics in the two models are different and they produce qualitatively different transitions. The relatively sharp movements in trade in the inventory model are observed in response to business cycle shocks and thus explain some of the high cyclicality in recessions and recoveries.[15]

The exercises in the section make it clear that the nature of the firm-level trade frictions determine the nonlinear aggregate trade dynamics we observe in the data, in terms of both the slow and fast adjustment to shocks. Comparing the static and dynamic models, we find that the consumption dynamics in the static models differ substantially from the dynamic models. These findings imply that the sufficient-statistic formulas for the gains from trade derived from static models do not apply to models with firm-level trade dynamics. Put differently, if the true data-generating process is one of these dynamic models, applying the static formulas period-by-period would provide a poor approximation of the aggregate impact on consumption or welfare. Likewise, the path of shocks estimated from a static model would be quite different than the true shocks.

5 Uncertainty and the future

Once we move from static to dynamic trade models, we can address questions regarding the firm-, industry-, and aggregate-level uncertainty that firms face in the foreign market. In the dynamic models we have reviewed, the expected level and variance of future shocks will influence the current level of trade, although the direction and magnitude of these effects

[15] Khan and Khederlarian (2019) find evidence of this type of short-run overshooting in response to NAFTA, followed by a gradual increase in the trade elasticity over the next 5 to 10 years.

depend on model specifics. A nascent research agenda focuses on identifying, empirically and theoretically, the effects of future shocks on current outcomes and uses current outcomes to identify the expected path of future shocks. A key open challenge is to separate the impact of expected future changes from the uncertainty over these changes.

The evidence on the effects of idiosyncratic uncertainty on trade flows is mixed. The empirical work mostly emphasizes differences across products, rather than the overall level of trade. Using French customs data, Békés et al. (2017) find that firms export less in products with higher demand volatility, and do so by exporting less frequently but in larger shipments. Clark et al. (2014) find that goods with greater uncertainty in ocean freight delivery times have lower trade flows. In a theoretical exploration, Alessandria et al. (2015) find that an increase in the volatility of idiosyncratic productivity will increase trade flows, even if it reduces the export participation rate: Greater dispersion in outcomes makes the most productive exporters more profitable, boosting their size and returns to exporting.

With respect to aggregate uncertainty, the evidence, again, is mixed. Most work has focused on the role of exchange-rate uncertainty and trade flows. Bahmani-Oskooee and Hegerty (2007) review this largely inconclusive work. Merga (2019) proposes novel methods to identify stochastic exchange-rate volatility, and finds that greater volatility decreases trade. He shows that a sunk-cost model, expanded to include shipping delays and financial constraints, can generate such an outcome. In contrast, Caldara et al. (2020) and Steinberg (2019) study trade-policy uncertainty in general equilibrium sunk-cost models and find increased trade-policy uncertainty may increase trade and even output, although Caldara et al. (2020) find a negative impact of trade-policy uncertainty when there are price rigidities.

There is a renewed interest in the aggregate and idiosyncratic uncertainty surrounding trade policy.[16] Influential work by Handley and Limão (2017) uses the granting of permanent normal trade relations (PNTR) to China to identify a dampening effect of uncertain future tariff increases on trade. In a sunk-cost model, trade volumes fall as uncertainty rises, and

[16] An early example is Ruhl (2010), who studied the ban of Canadian beef exports following the discovery of "mad cow disease" in Canadian cattle. This ban was unexpected, instantaneous, and of an uncertain duration, providing a clean experiment. This type of uncertainty, however, is less common than uncertainty over future tariff levels.

they use this relationship to estimate the likelihood of a future tariff increase. Alessandria et al. (2019) revisit this episode using within-year variation in trade flows and the timing of annual U.S. congressional votes on Chinese-good tariffs. They find that, in the lead up to a congressional vote, trade expanded more in products with a potential tariff increase. This behavior implies a smaller likelihood of non-renewal of China's PNTR than Handley and Limão (2017) estimate. Caldara et al. (2020) construct a firm-level measure of trade policy uncertainty from earnings calls and identify heterogeneous expectations of future trade policy across firms. Firms most concerned about future policy have weaker investment growth. Crowley et al. (2018) show that firm entry rates fall and exit rates rise in the presence of a future, uncertain increase in tariffs identified through the tendency of anti-dumping duties on a product to spread across countries.

A related issue is the differential response of export decisions to temporary and permanent changes in the economy. Trade policy can be long-lived (free trade agreements) or temporary (antidumping duties); business cycles can induce high-frequency changes in the exchange rate and economic crises can generate long-lived changes. Long-lived changes will have a larger effect on the future value of a firm and induce a larger response on the extensive margin. This is the argument made by Ruhl (2008) to explain why observed trade volumes are more responsive to tariff changes (which are permanent) compared with movements in the real exchange rate (which are transitory).

6 Conclusions and future research

We have reviewed the overwhelming evidence that firms are making dynamic decisions to participate in foreign markets. The nature of these investments is identified through entry, exit and the expansion within and across markets. The analysis of general equilibrium models with firm dynamics has been limited, but the aggregate outcomes of these models differ substantially from static models. Put simply, static models do not approximate the short-run or long-run outcomes of a dynamic adjustment processes.

We view this as an opportunity to revisit many of the findings in the literature and to ask questions that cannot be answered in static models. Perhaps the most important are questions regarding trade policy. How does uncertainty in policy, temporary policy, and preannounced future policy influence firm choices and, in turn, aggregate quantities and prices? How do we measure the effects of policy on aggregate trade and output growth? This last question is probably the most important, since, after nearly 40 years of sustained integration, the transition seems complete and the future direction of trade policy is in doubt.

Isolating the effects of a change in tariffs from other shocks remains an open question. The anticipation effects of announcements, such as Britain's vote to leave the European Union, are vivid in reports of Londoners stockpiling Nutella, but remain to be carefully studied. The large movements in stock prices and exchange rates on news of the U.S.-China trade war will need to be reconciled with theory, and there are growing concerns that the trade war may substantially slow growth and even plunge the world into recession. There are exciting opportunities to explore these and previous episodes in dynamic models of trade.

Finally, despite the careful modeling of entry costs, the literature has largely avoided the treatment of a firm's dynamic decisions across multiple destinations. The literature on (static) quantitative trade and firm heterogeneity has focused on the impact of geography on those costs. Merging these two approaches is a relatively unexplored, but promising, avenue of future research. Answers to the key questions referenced above, such as the effects of bilateral trade wars, may be critically affected by the exact nature of trade costs across destinations and the opportunities for market switching.

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