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Foreign Customer Accumulation and Export Dynamics

by

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Abstract

I present a dynamic fixed cost model of export participation extended by a capital theoretic concept of the customer stock. Plants that want to start exporting have to invest into a market specific factor which serves as input into a decreasing returns to scale technology generating sales demand. Customer capital, like phyical capital, depreciates over time and its accumulation is subject to adjustment costs. It allows the model to reproduce the empirical fact that new exporters show above average revenue growth rates and a declining exit hazard in the years after entry. I structurally estimate the model on a rich panel data set of German manufacturing plants between 1995 and 2008. During the observed time span, plants in the sample saw a strong increase in export activity which provides a suitable case study for the predictive power of the model. Unlike a pure fixed cost version, the model correctly forecasts a steep rise in exports after 2003. It is also able to reconcile a strong export reaction to trade liberalizations with a low elasticity of aggregate exports to exchange rate movements. Customer capital accumulation therefore offers a potential resolution to the elasticity puzzle in international economics.
Keywords: customers as capital, firm entry, firm heterogeneity, export dynamics, sunk costs, international business cycles
JEL: E32,F14,F17,F40,F41,F44

1 Introduction

New plants, after setting up production and entering a market, typically lag behind their industry competitors in terms of sales for a number of years. This holds true even for highly commoditized products where entrants and incumbents produce very similar products. An intuitive explanation for this phenomenon is that new producers are simply less efficient than their experienced competition and take a long time to catch up in terms of process and

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organizational know-how. A recent line of literature questions this supply side explanation and presents evidence that hints at demand side forces as determinants of the fate of young plants. Foster et al. (2012) use price information from the Census of Manufactures to show that new plants actually possess a small advantage in physical productivity compared to incumbent plants. Instead, their lower sales volumes seem to be the result of insufficiently many customers to sell to.

If indeed, new customers are so hard to come by, this micro friction has potentially important macroeconomic implications. Entrants are by no means the only plants facing the problem of finding new customers to sell to. Any plant, after a positive productivity shock would have to invest time and resources into building marketing and distribution capacities to exploit productive potential. In international economics, the presence of such market expansion friction might provide an explanation for what has been termed the *elasticity puzzle* - the discrepancy between high estimated elasticities of substitution between goods produced in different countries from trade liberalization episodes and the low elasticities needed to reproduce the co-movement of exports and real exchange rate at business cycle frequency. Persistent tariff reductions should induce exporters to larger investments into their export demand leading to larger trade reactions than transitory exchange rate variations.

This paper explores the macroeconomic implications of slow and active demand accumulation within the context of a dynamic model of plant exporting behavior. It introduces the notion of "customer capital" into a set-up in which plants differ in terms of revenue productivity and exporting is subject to sunk entry and fixed costs that has become the workhorse for empirical studies of export participation. I structurally estimate the model on a new panel data set of German manufacturing firms between 1995 and 2008. The substantial expansion in exporting that German manufacturing experienced during this time serves as an important case study on which to test the model's empirical predictions. The estimated model implies that during the observed time period the average plant spends between 26 and 38 percent of export revenue on building and maintaining a customer stock in export markets. The estimated demand elasticity in the export market of 1.42 is well within the range typically calibrated in international business cycle models. The model predicts a low elasticity of aggregate exports with respect to real exchange rate movements. The predicted much larger trade gains after a tariff elimination are in the same order of magnitude as those predicted by a more standard fixed costs model.

The model setup builds on the large literature of estimated dynamic models of export participation. The paper most closely related is Das et al. (2007). To their model I introduce the notion of a consumer base in export: Firms have to accumulate consumer-capital in order to sell in the foreign market. I assume that there are DRS in generating demand from investing in a consumer base. This technology may be broadly interpreted as follows: tt encompasses advertising expenditure on building brand reputation as well as the establishment of a network of local buyers and distribution channels. The unifying feature of these activities is that they take time and money to complete and additional benefits become increasingly more expensive. Customer capital, like physical capital, depreciates over time and is subject to adjustment costs. Exports are subject to an ad valorem tariff which may vary over time and exporters have to form expectations over aggregate export demand and the real exchange rate which vary stochastically.

The paper uses the AFiD Panel of Industrial Establishments, a plant level panel maintained by the German national statistical agency to estimate the model parameters. With more than 50,000 plant observations per year, it provides extensive coverage of the German manufacturing sector and spans the years 1995 to 2008. During the observed time period, the sector experiences a strong expansion in export activity. Export participation by plants in the sample rises from 54 to 65 percent and total export revenue doubles in real terms. This expansion was the result of a drop in worldwide tariffs after the conclusion of the Uruguay round in 1995, a strong expansion in demand especially in transition economies, and favorable exchange rate movements in the initial years of the sample.

I use the data to structurally estimate the model parameters using a simulated method of moments (SMM) estimator. After solving the plant problem by value function iteration, I simulate the export behavior of plants to obtain a panel data set of the same size as the underlying data set. During the simulation, I feed in the observed time series for aggregate tariffs, export demand and real exchange rate. I obtain estimates by minimizing a quadratic form criterion function in a vector of data moments.

This paper is the first to obtain an estimate from plant level data of the marketing costs plants occur to maintain and increase their customer stock in export markets. The estimated costs are large and account by far for the largest share of export costs. In 1995, the beginning of the sample for example, the average exporter spent 2.4 million euros on maintaining customer capital and a further 0.96 million on expanding it. Estimated entry costs into exporting of 33,467 1995 euros are relatively small when compared to other estimates in the literature.

The estimation procedure succeeds in matching the chosen target moments well, in particular when comparing growth rates and survival probabilities for new exporters. Its predictions on export participation are well in line with the data up to 2006 after which it misses a further surge in export participation. It closely matches the shape of the growth in total export revenue while overpredicting its absolute size. Importantly, when compared to an estimated restricted model version in which plants face fixed costs of exporting only, the baseline correctly predicts a further surge in exporting revenue after 2003 while the fixed cost model predicts exports flat and even declining.

I use three different scenarios to compare the dynamic implications of the baseline model to a more standard sunk/fixed cost model of exporting: a real exchange rate depreciation, an increase in worldwide demand and an elimination of all export tariffs. Aggregate exports in the fixed cost model react almost twice as strong to a real exchange rate deprecation compared to the in baseline model with estimated elasticities of 3.4 compared to 1.9. Meanwhile, both models predict gains of total exports of 10 to 11 percent when moving to free trade. In case of the baseline model, however, these take almost ten years to fully realize. So, unlike the fixed cost model, the estimated baseline model can reconcile large predictions of trade gains after a tariff reduction with a subdued reaction of aggregate exports to a real exchange rate depreciation. Slow and active demand accumulation therefore quantitatively manages to provide an answer to the elasticity puzzle.

This paper builds on a long line of literature in empirical trade that estimates structural and reduced form discrete choice models of export participation on plant or firm level data. Some of the most prominent examples are Roberts and Tybout (1997), Bernard and Wagner (2001), Bernard and Jensen (2004) and the aforementioned study by Das et al. (2007). Willis and Ruhl (2009) and Arkolakis (2010) point out that the predictions of these models are at odds with the observed increasing survival rates for new exporters and the above average export growth rates among small exporters following trade liberalizations.

A number of recent contributions has therefore started to extent this framework by broadening the focus beyond mere participation. Fitzgerald and Haller (2012) use plant level information on export destinations and sales by 6 digit tariff line from Irish manufacturing firms to show that lagged export sales are an important predictor of future trade participation. They also interpret this as evidence of some market specific demand factor that plants have to accumulate over time. My paper differs in its use of a structural estimation approach which allows me to quantify the costs associated with foreign customer accumulation and to conduct counterfactual experiments. Eaton et al. (2012) combine Columbian plant level data with U.S. Customs data to establish patterns in individual sales relationships between the Columbian plants and their U.S. buyers. They then propose a continuous time search model with heterogeneous buyers. The evidence they provide is mostly consistent with the model and data of this paper. One may think of the search friction as micro foundation for the demand technology I assume. Arkolakis (2010) also proposes a static model of costly costumer accumulation to reconcile theory and data.

The idea of the customer stock being a capital good has recently also received attention in the macroeconomics literature. Gourio and Rudanko (2011) introduce a search friction in product markets into a closed economy general equilibrium model and show how it affects firm level variables and the relation between investment and Tobin's q. Drozd and Nosal (2012), in a homogeneous firm two-country model, show that modeling international sales relations as capital good helps in replicating the observed relative volatility of terms of trade and real exchange rate.

This paper proceeds as follows. Section 2 presents the model. In Section 3, I introduce my data set, discuss sample selection, and establish some stylized facts which indicate a slow process of demand accumulation for new exporters. I also report how I calculate series for aggregate tariffs, export demand and the real exchange rate. Section 5 presents parameter estimates, evaluates model fit and discusses what implications they have for the cost of exporting. Section 6 contrasts the dynamic behavior of the model to that of a more standard fixed cost model. Section 7 concludes.

2 A model of export participation and intensity choice

The section presents a dynamic model of plant export participation and costly customer accumulation. Like in much of previous literature, exporting is subject to sunk entry and fixed participation costs. I extent the framework by the notion of *customer capital* in the export market. After entering into exporting, plants first have to spend resources on acquiring a stock of customers to sell to. This includes advertising expenditures on building brand reputation as well as the establishment of a network of local buyers and distribution channels. In the model, this concept takes the form of a capital good that the firm has to spend resources on in acquiring and which generates demand through a decreasing returns to scale technology[1]. Like physical capital, it depreciates geometrically and is subject to convex adjustment costs in the size of gross investment. The latter imply that plants take several years after entering the market to reach their desired market size. They also induce a decreasing exit hazard over time as plants have more customers to sell to. When a firm chooses not to export in any year, it starts its next exporting episode having to build up its entire customer base anew. The sunk component in exporting costs therefore increases as firms grow bigger.

In the part of the export market that a plant has acquired access to, it behaves as monopolistic competitor which rules out strategic considerations in pricing. Other than on its price, a plant's profits from exporting depend on idiosyncratic shocks to export demand and production costs and aggregate movements in real exchange rate, tariffs, and total income in export markets. Idiosyncratic profitability, real exchange rate and aggregate demand follow known Markov processes over which the plant has to form expectations. The model focuses on the export market to keep the already highly dimensional model tractable and focused. The abstraction from the home market implies that home and foreign market are independent in terms of consumer base.

2.1 Export Revenues and Profits

When plant i chooses to export in a given period t, it faces the following demand schedule in its export market

$$q_{it}^{D} = \epsilon_{it} p_{it}^{*-\eta} D_{it}^{\alpha} D_{t}^{W}. \tag{1}$$

ϵ_{it} is a shock that shifts the idiosyncratic demand schedule. p_{it}^{*} is the price in foreign currency terms that the plant sets for its product . D_{it} is the size of the customer base that the firm has accumulated in foreign markets. I will discuss the details of how a firm accumulates market share below. The assumption that $0 < \alpha < 1$ implies that *customer capital* is subject to decreasing returns to scale. D_{t}^{W} represents aggregate demand in export markets. It, too, evolves stochastically[2].

[1] Given my assumption of linear costs in accumulating costumers, decreasing returns imply an interior solution for the target market size.

[2] Equation (1) would follow naturally from the assumption of a CES consumption aggregator in the export market. In that case, D_{t}^{W} would be total consumption and D_{it}^{α} would measure the intensity, with which plant i has penetrated the market, i.e. the amount of customers it can reach.

Export sales are subject to an ad valorem tariff τ_t, which may evolve over time. The real exchange rate in period t is denoted by RER_t. The foreign demand schedule therefore implies the following revenue function dependent on goods sold q_{it}:

$$R\left(q_{it}\right)=\frac{RER_t}{1+\tau_t}q_{it}^{\frac{\eta-1}{\eta}}\epsilon_{it}^{\frac{1}{\eta}}\left(D_{it}^{\alpha}D_t^W\right)^{\frac{1}{\eta}}.$$

Plants face variable costs of production c_{it} such that gross profits from exporting are given by:

$$\pi_{it}=R\left(q_{it}\right)-c_{it}q_{it}.$$

Profit maximization implies that plants choose prices as a fixed mark-up over variable production costs: $p_{it}^*=\frac{\eta}{\eta-1}\frac{1+\tau}{RER_t}c_{it}$. In my data I observe a plant's export revenue denoted in terms of domestic currency but no information on production costs and therefore no direct measure of gross profits from exporting. However, given the previously made assumptions, optimal pricing implies that profits are a fixed fraction of revenues: $\pi_{it}=\frac{1}{\eta}R_{it}$. Per period gross profits from exporting evaluated using optimal prices are therefore given by:

$$\pi_{it}=\frac{1}{\eta}\left(\frac{\eta-1}{\eta}\right)^{\eta-1}\epsilon_{it}c_{it}^{1-\eta}D_{it}^{\alpha}D_t^W\left(\frac{RER_t}{1+\tau_t}\right)^{\eta}.$$

I normalize constants to one and define $z_{it}=\epsilon_{it}c_{it}^{1-\eta}$ as a composite state for idiosyncratic export profitability. For the estimations, this allows me to work with the following relatively simple equation for potential export profits:

$$\pi_{it}=z_{it}D_{it}^{\alpha}D_t^W\left(\frac{RER_t}{1+\tau_t}\right)^{\eta}. \tag{2}$$

It is also z_{it} for which I make distributional assumptions and over which the firm forms expectations. More specifically, I assume idiosyncratic export profitability to be the sum of a fixed component χ_i and a persistent component ϕ_{it}:

$$z_{it}=\phi_{it}+\chi_i.$$

The permanent component χ_i is a realization of a log-normal distribution $\ln N\left(0,\sigma_\chi^2\right)$. The logarithm of ϕ_{it} follows an AR(1) process with innovations ε_{it}^{ϕ} drawn from a normal distribution with zero mean and variance σ_ϕ^2:

$$\ln\left(\phi_{it}\right)=\rho_\phi\ln\left(\phi_{it-1}\right)+\varepsilon_{it}^{\phi}.$$

2.2 Costs of Exporting

A firm that wants to export in any given period faces two types of costs: a stochastic fixed overhead and costs of maintaining or increasing its foreign customer stock. The fixed cost is on average higher, when the firm has not been an exporter in the previous period and therefore has a sunk component. It represents administrative costs and costs of complying with foreign regulations and customs procedures. Those are unlikely related to the amount of exporting a firm does. In addition, penetrating the export market means having to acquire customers via marketing and potentially building up a network for distribution and sales[3]. I treat foreign demand potential D_{it} as a capital good like in Arkolakis (2010), Drozd and Nosal (2012), and Fitzgerald and Haller (2012). It depreciates over time and its accumulation is costly and subject to convex adjustment costs. Convex adjustment costs mean that a firm, after entering into exporting, will take a number of years to build up its desired stock of foreign customers.

2.2.1 Costs of accumulating a customer base

A plant that did not export previously enters the year without any customers in foreign markets. A plant that served D_{it-1} customers last year, retains a fraction of $(1-\delta)$. Other supply relations dissolve, because partners in foreign markets go out of business, and built up reputation from previous marketing campaigns becomes less valuable. Before determining its export volume for the current year, the plant has the opportunity of investing into its customer stock. Accumulating additional units of $I_{it} = D_{it} - (1-\delta)D_{it-1}$ costs $c^{lin} I_{it}$ in terms of current profits. Additionally, it has to pay quadratic adjustment costs $\frac{c^{conv}}{2}\left(\frac{I_{it}}{D_{it}}\right)^2 D_{it}$ on its investment. The total costs of investing $c\left(D_{it}, D_{it-1}\right)$ are:

$$c\left(D_{it}, D_{it-1}\right) = c^{lin}\left(D_{it} - (1-\delta)D_{it-1}\right) + \frac{c^{conv}}{2}\left(\frac{I_{it}}{D_{it}}\right)^2 D_{it}.$$

2.2.2 Fixed Costs of Exporting

A firm that did not export in the previous year needs to pay a sunk entry cost $\gamma_E - \xi_{it}^E$ where $\xi_{it}^E \sim N\left(0, \sigma_E^2\right)$. If it has exporting experience from the last year, it pays a fixed cost of $\gamma_F - \xi_{it}^F$, where $\gamma_F < \gamma_E$ and $\xi_{it}^F \sim N\left(0, \sigma_F^2\right)$. Letting $y_{it} \in \{0,1\}$ denote the export state of plant i in period t, per period net profits from exporting can be summarized by:

$$u\left(\phi_{it}, \chi_i, D_{it}, D_{it-1}, RER_t, D_t^W, \tau_t\right) = \begin{cases} \pi_{it} - \gamma_F + \xi_{it}^F - c(D_{it}, D_{it-1}) & y_t = 1 \wedge y_{t-1} = 1 \\ \pi_{it} - \gamma_E + \xi_{it}^E - c(D_{it}, 0) & y_t = 1 \wedge y_{t-1} = 0 \\ 0 & y_t = 0 \end{cases}$$

2.3 Bellman Equations

In any given year t, a plant observes the current realizations of ξ_{it}^X,ϕ_{it},RER_t, D_t^W. It then decides whether to participate in the exporting business this period. If it does, it also decides how much to invest into its customer stock and sets prices thereafter. Prior to 1995, plants expect the current tariff level to persist forever. In 1995, they learn the whole

[3] Alternatively, the firm can outsource marketing and distribution to local subcontractors. In this case, it probably has to find different subcontractors for different regions such that the costs of distribution network are still increasing in its size.

tariff sequence up to 2008. They assume that from 2008 on, tariffs will stay at that level forever. Dropping time subscripts for all variables except τ and denoting future values of a variable x by x', I summarize the dynamic problem for the firm using two Bellman equations:

– *For plants that exported in the previous period*

$$\begin{aligned} V^1(\xi^F, \phi, D_{-1}, RER, D^W, \tau_t) = \quad & \max\Big[\max_D\{\pi - \gamma_F + \xi^F - c(D, D_{-1}) \\ & +\beta\mathbb{E}\left[V^1\left(\xi^{F\prime}, \phi', (1-\delta)\,D, RER', D^{W\prime}, \tau_{t+1}\right)\right]\}, \\ & \beta\mathbb{E}\left[V^0\left(\{\xi^{E\prime}, \phi', RER', D^{W\prime}, \tau_{t+1}\right)\right]\Big] \end{aligned} \tag{3}$$

– *For plants that did not export in the previous period*

$$\begin{aligned} V^0(\xi^E, \phi, RER, D^W, \tau_t) = \quad & \max\Big[\max_D\{\pi - \gamma_E + \xi^E - c(D, 0) \\ & +\beta\mathbb{E}\left[V^1\left(\xi^{F\prime}, \phi', (1-\delta)\,D, RER', D^{W\prime}, \tau_{t+1}\right)\right]\} \\ & \beta\mathbb{E}\left[V^0\left(\xi^{E\prime}, \phi', RER', D^{W\prime}, \tau_{t+1}\right)\right]\Big] \end{aligned} \tag{4}$$

3 Data

This section introduces the data set, the *AFiD Panel of Industrial Establishments* maintained by the German national statistical agency. It contains on average more than 50,000 establishments per year and covers the years 1995 to 2008. During the observed time period, German manufacturing experienced an exporting boom. Export participation in the sample rose from 54 to 65 percent and the (unweighted) average revenue share of exporting increased from 22 to 28 percent. As a result, aggregate real export revenue doubled.

After briefly describing sample selection, in Section 3.3 I provide further evidence from the data set that plants after entering the export market face important demand side frictions. In the first four years of an exporting spell, entrants have on average higher growth rates than incumbents. While the year of entry is associated with a healthy increase in domestic revenues, pointing to an initial increase in productivity, it is not sustained in the following years. This is evidence against upgrading in physical productivity as result of exporting. Also, survival probabilities are an increasing function of exporting tenure.

In Section 3.4 I discuss how I calculate tariffs. The year 1995, the beginning of the data set, saw the conclusion of the Uruguay round of trade negotiations which resulted in the creation of the WTO and a commitment to substantial tariff reductions for the trade in manufacturing goods from joining nations. Those were to be gradually phased in until 2000 for developed and until 2004 for developing countries. Also, in 2004 ten mostly Eastern European countries joined the EU which meant that German firms could now access those neighboring markets tariff free. As a result, the trade weighted average value added tariff for German manufacturing exports dropped from about 3.3 percent in 1995 to about 2.1 percent in 2008.

Simultaneously, real per capita income in many emerging economies started growing strongly. Market size in those countries relative to the German home market increased by more than thirty percent. Section 3.5 discusses how I calculate a time series for real aggregate export demand. Finally, in Section 3.6 I present the real exchange rate series. Germany's effective real exchange rate in 1995 had just strongly appreciated after the calamities in the European Exchange Rate Mechanism that forced out Britain and caused Italy to depreciate against the German Mark. In the years up to 2000, Germany devaluated by more than 20 percent against its trade partners. Until the end of the sample, it appreciated again by about 10 percent.

3.1 AFiD - Administrative Firm Data for Germany

My data set is the *AFiD Panel of Industrial Establishments.* It is an annual, administrative plant-level panel maintained by the German statistical agency. It samples from the universe of German manufacturing establishments with 20 or more employees. In sectors with predominantly smaller firms, this cut-off can be substantially lowered. Participation for the sampled plants is mandated by law. A plant is counted as an individual unit if it is locally separated from other establishments belonging to the same firm. Ownership is recorded, but does not influence sampling. Establishments owned by German firms in other countries are not included.

The sample covers the years 1995 to 2008. Variables collected include total revenue, total export revenue, employment, hours worked and investment. One of the appeals of the data set is its coverage. It comprises an average of about 50,000 plants per year. The panel is unbalanced but plants tend to stay in the sample quite long such that an uninterrupted series of 14 observations exists for 26,522 plants and about 10,000 more have at least 10 years worth of observations. Sectorial classifiers allow to group plants into *NACE rev. 1.1* sectors.[4] All NACE sectors related to manufacturing and the extractive industries are covered (NACE 10-36). [5]

3.2 Sample selection and summary statistics

I first delete every observation from the data set that has missing information on employment, total revenue and export revenue. In order to eliminate plant-year observations which are potentially the result of misreporting, I also delete for every year separately observations which are in the top and bottom percentile for employment or total revenue growth[6]. The resulting sample contains 667,601 plant-year observations from 81,913 different establishments.

[4] For further information on the methodology behind the NACE classification and its relation to other systems of industry classification, you may consult Eurostat.

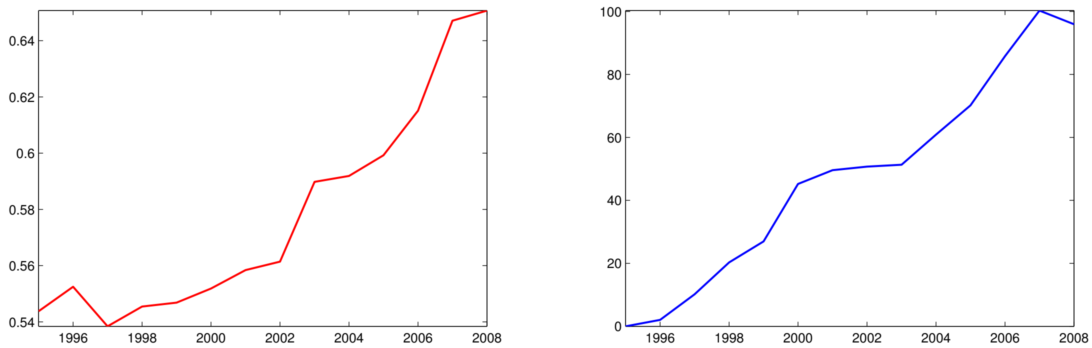
[5] The interested reader finds more information on the data set in Appendix A. Tables 6 - 7 reports sample splits by sectoral classification, firm type and employment size categories. All of them use the year 1999 as an example.

[6] This criterion is no applicable for export revenue growth. Because of the way I measure growth rates, the top and bottom percentile of export revenue growth rates would largely contain episodes of exit and entry

Figure 1: Export participation and total exports in AFiD (1995-2008)

(a) Export participation

(b) Growth in aggregate export revenue



Note: The figure illustrates trends in the exporting behavior of the plants in the data set during the observed time period. Panel (a) shows the percentage of plants with positive export revenues. Panel (b) reports the growth in real aggregate export revenue.
Source: FDZ der Statistischen Ämter des Bundes und der Länder, AFiD-Panel Industriebetriebe, 1995-2008, author's calculations.

Historically always export oriented, the German manufacturing sector grew even substantially more so during the time of our sample. As Figure 1a shows, the percentage of firms in the sample engaged in some form of exporting activity grew by more than 10 percentage points from about 54 percent 1995 to about 65 percent in 2008. Conditional on being an exporter, export revenue grew also more important as a share of total revenue. The average export revenue share rose from less than 22 percent in 1995 to more than 28 percent in 2008. Figure 1b shows that as a consequence of this expansion on the extensive and intensive margin, real total exports doubled between 1995 and 2007.

As illustrated in Figure 7 in the appendix, the expansion in export participation was the result of high entry rates and a steady decline in exit rates from exporting. Nonetheless, even though export participation as a whole increased substantially during the sample period, turnover between exporting and non-exporting remained high. Even in the boom year of 2006, more than two percent of plants with positive export revenue in 2005 did not report any exporting in 2006.

3.3 Evidence for slow demand accumulation

In a recent contribution, Foster et al. (2012), using data from the US Census of Manufacturers, show that entrants into the US domestic market are much smaller than their established industry competitors, and that they may take over a decade to close the gap in sales. Using price data, they can show that these size differences are not the result of lower productivity but rather of a lack customers to sell their products to. Established firms entering into exporting should face a similar problem. They, too, first have to establish distribution channels, explore and penetrate markets and build a reputation with customers. These are both time- and resource consuming activities that imply that it takes young exporters a number of years to reach their desired export volumes. These entry episode therefore serve as another good test case on which to evaluate the hypothesis of demand side impediments to plant growth.

Table 1: Sales growth rates for new exporters

Year after entry	**Sales growth**	
	Export	Domestic
0	2.000	0.093
1	0.288	-0.011
2	0.060	-0.017
3	0.059	-0.016
4	0.040	-0.015

Note: The table displays growth rates for plants who enter into exporting for export revenue (column 1) and domestic revenue (column 2) conditional on surviving as exporter. I count the year when the plant enters into exporting as year zero. Growth rates are calculated as $\frac{x_t - x_{t-1}}{.5(x_t + x_{t-1})}$. This statistic is bounded between -2 (exit) and 2 (entry).
Source: FDZ der Statistischen Ämter des Bundes und der Länder, AFiD-Panel Industriebetriebe, 1995-2008, author's calculations.

As documented in the previous subsection, due to high turnover and a substantial net expansion in export participation, entrance into exporting is a very frequent occurrence in my data set. In total, there are 14,814 observations where a plant shows a switch from non-exporter to exporter. I exploit this fact to test hypothesis on sales behavior during the years after entry. Table 1 reports mean sales growth rates for entrants into exporting in foreign and domestic markets. Throughout the paper, I calculate growth rates as $(x_t - x_{t-1})/(.5(x_t + x_{t-1}))$. This measure, first introduced by Davis et al. (1998), has the advantage of being bounded between -2 and +2, which allows to include market entry and exit.

There are two observations one can make from the table. For one, conditional on surviving as an exporter, in the first four years after entering into exporting, new exporters show on average higher export sales growth rates than incumbent exporters. The average export sales growth rate over all plants and years is 0.051. Second, while entering into exporting is also associated with a healthy increase in domestic sales which points to a positive productivity innovation, this cannot be said for the subsequent years which all display negative growth rates (which are consistent with mean reversion in productivity). In combination, these two observations suggest that while entering into exporting is associated with a productivity increase, subsequent growth in export sales is not the result of further improvements in productivity. Instead, improved demand conditions seem to be responsible for the strong export sales growth in the year following entry.

Table 2 illustrates another fact that hints at the accumulation of some export market specific factor: the probability of surviving as an exporter is an increasing function in the number of years already spent exporting. While sunk fixed costs in entering exporting would explain hysteresis in the exporter status, their combination with mean reversion in

Table 2: Survival probabilities for new exporters

Year after entry	Probability of survival
0	67.9
1	82.6
2	87.3
3	89.7
4	92.0
5	91.7
6	93.1
7	94.4
8	95.5

Note: The table displays survival probabilities as exporter in the years after entering into exporting. For example, shows that for firms who report export revenue after having had not exported in the first year, the chance of again exporting in the next year is 67.9 percent.
Source: FDZ der Statistischen Ämter des Bundes und der Länder, AFiD-Panel Industriebetriebe, 1995-2008, author's calculations.

revenue productivities still implies a decreasing survival probability as more firms firms revert below the continuation threshold.

3.4 Tariff data

The AFiD data set does not record plant level information regarding export destination country. The only variable recorded is total export revenue. In order to empirically identify the effect of variations in tariff duties on export participation and sales, I construct a yearly average measure of tariff duties that German manufacturing exports were subject to between 1995 and 2008. Export data by sector are available from the Eurostat Comext data base[7] and recorded according to the Harmonized System (HS) classification as is the norm with trade data. I manually construct matches between NACE (rev 1.1) sectors and HS(2) chapters and obtain dissaggregate export data for the relevant sectors. In order to construct a stable world market aggregate for the time period, I then rank export destinations by trade value for every year. The union set of the top twenty partners in every year constitutes the world market. The set stably accounts for about 80 percent of total German manufacturing exports. Please consult Appendix D for more details on this procedure and for a list of the export destinations included.

I then obtain 6-digit tariff line data from the WTO[8] and match them with the export data from Comext to calculate an average trade-weighted measure for add-valorem export duties during the sample period. The resulting time series is displayed in Figure 2a. With an average of only 3.3 percent, tariff duties on German exports were already low at the beginning of the sample period. The trade liberalizations described in the introduction to

[7]For more details see `http://epp.eurostat.ec.europa.eu/newxtweb/`
[8]`http://www.wto.org/english/tratop_e/tariffs_e/tariff_data_e.htm`

this section are well visible in the series. Between 1995 and 2000, the tariffs drop by a full percentage point to 2.2 percent as a result of the implementation of the Urugay tariff reductions and abolitions. In 2004, the accession of ten mostly Eastern European countries to the European Union means exports to those destinations are now tariff-free which has aggregate tariffs drop by another .3 percentage points.

3.5 Aggregate export demand

In my model, there are four reasons why export revenue for a plant grows. The plant may expand its penetration of world markets by investing into its stock of customers. It may experience an increase in revenue productivity. The value of exports in domestic currency terms may shift because of favorable exchange rate movements. Tariff reductions increase the share of sales revenue the plant retains. Finally, aggregate import demand in the part of the world that the plant has penetrated grows with aggregate income.

I use the same set of countries from the calculation of the tariff series to obtain a world demand series. Total demand in country i at time t in real terms is given by

$$D_{i,t} = GDP_{i,t} + IM_{i,t} - EX_{i,t}$$

where $GDP_{i,t}$ is real GDP and $IM_{i,t}$ are $EX_{i,t}$ are real aggregate imports and exports. The time series for these variables are taken from the World Bank Development Report[9] and the IMF Global Economic Outlook[10] . The resulting aggregate demand series series by country are then averaged and weighted by total German manufacturing exports. Finally, I make the assumption that the costs of exporting (production costs and other) are growing at the same rate as domestic demand. The relevant series for evaluating export profitability is therefore $\frac{D_t^W}{D_t}$, world demand relative to domestic demand. Normalizing relative aggregate export demand in 1995 to 1.0, the resulting time series is displayed in Figure 2b. Between 1995 and 2005, total export demand relative to domestic demand grows by 27 percent, a level at which it stays more or less constant until the end of the observed time period.

3.6 Real exchange rate

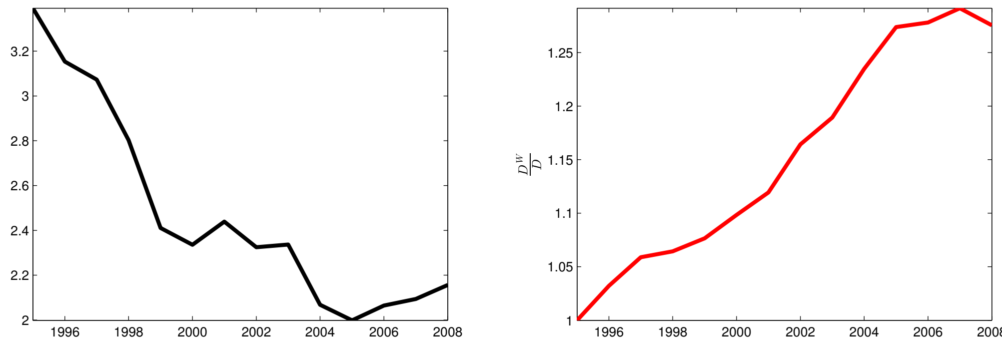
The real exchange rate data are from the Bank for International Settlements (BIS). Ideally, one would want to calculate the real exchange rate for the same set of countries used for calculating tariffs and aggregate demand series. Meanwhile, especially for the emerging market economies which are are part of the world aggregate, consistent inflation data for this time period is hard to obtain. I therefore use the BIS data as the closest approximation. The BIS time series is based on a trade basket of 51 partner countries going back to 1994. There also exist a longer time series going back to 1964 based on 22 trade partners. My estimations of the real exchange rate process below are based on a series where I splice the series based on the more narrow basket until 1993 to the series based on the broader

[9] Available at `http://databank.worldbank.org/Data/Home.aspx`
[10] Available at `http://www.google.com/publicdata/explore?ds=k3s92bru78li6_&hl=en&dl=en`

Figure 2: Aggregate series

(a) Trade weighted tariff series

(b) Aggregate export demand series (1995=1)



Note: Panel (a) displays the trade-weighted average tariff series for German manufacturing exports between 1995 and 2008. To calculate the series, I match average across HS(6) tariff lines for manufacturing exports and weight them by tradevolume for export destination and tariff line. Panel (b) displays world demand in the export market for German manufacturing relative to home market demand. The series is normalized to 1 in 1995. The export market is an aggregate of Germany's 23 most important trade partners weighted by trade volume.

basket. In the case of Germany, until about 1997, these two series almost coincide so there should be no problem of continuity.

The real exchange rate is calculated as the geometric weighted average of bilateral nominal exchange rates adjusted with the corresponding relative consumer prices. The trade based weighting methodology has its theoretical underpinnings in Armington (1969). The weights capture both direct bilateral trade and third market competition by double-weighting.[11] Please consult Appendix D for a display of Germany's real exchange rate during the sample period.

4 Estimation

This section describes how I estimate the model presented in Section 2 on the plant level data from the previous section. In a first stage, I make assumptions on the processes for the real exchange rate (RER_t) and world demand (D_t^W) whose parameters I estimate independently. This leaves $\Omega = \left\{\beta, \eta, \alpha, \delta, \rho_\phi, \sigma_\phi, \sigma_\chi, c^{lin}, c^{conv}, \gamma_E, \sigma_E, \gamma_F, \sigma_F\right\}$, a set of 13 parameters to be determined. I set β to an annual interest rate of 5 percent and estimate the other parameters using a Simulated Method of Moments (SMM) approach as developed by McFadden (1989), Lee and Ingram (1991), and Duffie and Singleton (1993). The twelve estimated parameters are collected in the parameter vector θ. Further information on how I solve for the establishment policy functions used in the simulation and on SMM itself can be found in Appendix E.

[11]For more details on the methodology, please consult Klau and Fung (2006).

4.1 Parameters estimated outside of the Model

I obtain parameter estimates for the real exchange rate process and aggregate export demand prior to estimating the remaining model parameters. Table 3 summarizes the estimated parameters and gives standard errors.

4.1.1 World demand process parameters

In my model simulation below, I assume D_t^W to follow a bounded random walk of the form

$$\log\left(D_t^W\right) = \max\left[\min\left\{\log\left(D_{t-1}^W\right) + \sigma_{DW}\epsilon_t^{DW}, \log(D_{max}^W)\right\}, \log\left(D_{min}^W\right)\right].$$

Section 3.5 explained how I calculate a times series for aggregate export demand for German manufacturing products between 1995 and 2008. I estimate σ_{DW} from the standard deviation of the growth rate of that series assuming that the random walk is not at its bounds. The boundedness assumption helps in assuring stationarity of the dynamic programming problem. After normalizing D^W to 1.0 in 1995, I pick $D_{min}^W = 0.75$ and $D_{max}^W = 1.5$ as lower and upper bounds. These turned out large enough to assure that further expanding them did not affect estimation results[12].

4.1.2 Real exchange rate parameters

I assume the annual real exchange rate to follow an AR(1) process in logs:

$$\log(RER_t) = \rho_{RER}\log(RER_{t-1}) + \sigma_{RER}\epsilon_t^{RER} \quad , \ \epsilon_t^{RER} \sim N(0,1)$$

The p-value of an Augmented Dickey-Fuller Test for non-stationarity on the real exchange rate series from 1973 (the end of Bretton Woods) to 2008 is 0.0139, so non-stationarity is rejected at the 5 confidence level. The point estimate of ρ_{RER} is 0.9073 with a standard deviation of 0.0968. In order to make my analysis comparable to that in previous studies, I stick to the assumption of a stationary exchange rate.[13] Table 3 summarizes the estimates for the processes for aggregate demand and real exchange rate. I obtain the standard errors for the innovation variances from bootstraps with 2,000 repetitions.

4.2 A Simulated Method of Moments Approach

A direct evaluation of the model's likelihood function in the parameter vector θ is infeasible. I therefore use a Simulated Method of Moments procedure. Its underlying idea is that, under the null hypothesis of a parameter estimate $\hat{\theta}$ being the true parameter vector θ_0,

[12] It should be noted that discounting by the plants and the fact that I am simulating the model over a finite number of periods mean that my results are unlikely to differ much from a model where D^W follows an unbounded random walk.

[13] As also discussed in Das et al. (2007), studies of real exchange rates dynamics fail to reject a random walk because of limited test power, while studies that exploit long time series or pool countries like Frankel and Rose (1995) are often able to do so.

Table 3: Estimated parameters for the aggregate stochastic processes

Parameter	σ_{DW}	ρ_{RER}	σ_{RER}
Estimate	0.0149	0.9073	0.0366
	(0.0025)	(0.0968)	(0.004)

Note: The table reports the estimated standard deviation of innovations to aggregate export demand (σ_{DW}), the persistence of the real exchange rate (ρ_{RER}) and the standard deviation of real exchange rate innovations (σ_{RER}). Standard errors are in parenthesis.

simulated panels of the same number of units N and of the same length T will on average yield the moments $\mu(\hat{\theta})$ observed in data set. Variations around the mean are the result of simulation uncertainty for the simulated data and sampling uncertainty for the observed moments. Simulations are therefore repeated S times over a fixed set of different stochastic draws and $\mu(\hat{\theta})$ is estimated by averaging over these draws. The challenge then is to identify a vector of moments $\mu(\theta_0)$ which is informative about the underyling parameters in the sense that $E_0 \frac{\partial \mu}{\partial \theta} \gg 0$ for as many entries as possible, i.e. the moments are responsive to changes in underlying parameters.

I obtain parameter estimates by minimizing the quadratic form criterion function

$$\left[\mu(\theta_0) - \frac{1}{S}\sum_{s=1}^{S} \mu(\hat{\theta})_s\right] W^{*-1} \left[\mu(\theta_0) - \frac{1}{S}\sum_{s=1}^{S} \mu(\hat{\theta})_s\right] \tag{5}$$

where W^* is the optimal weighting matrix $Var\left(\mu(\theta_0) - \frac{1}{S}\sum_{s=1}^{S}\mu(\theta)_s\right)$. As shown by Lee and Ingram (1991), under the null the variance-covariance matrix $Var\left(\frac{1}{S}\sum_{s=1}^{S}\mu(\theta)_s\right)$is equal to $\frac{1}{S}Var\left(\mu(\theta_0)\right)$. Independence of simulated and data moments then implies

$$Var(\hat{\theta}) = \left(1 + \frac{1}{S}\right)\left[E_0 \frac{\partial \mu'}{\partial \theta} W^{*-1} E_0 \frac{\partial \mu}{\partial \theta}\right]^{-1}. \tag{6}$$

I obtain $Var\left(\mu(\theta_0)\right)$ from (block-)bootstrapping the data 1,000 times with replacement. Setting $S = 20$ means that the standard error of $\hat{\theta}$ is increased by 5 % as result of simulation uncertainty.

Given a guess for the parameter vector $\hat{\theta}$, I solve the firm problem using value function iteration. I then simulate a panel of $N = 50,000$ plants S times over a fixed set of random draws feeding in the empirically observed time series for tariffs, aggregate demand and real exchange rate. During an initial period, I first let the economy settle into its stochastic steady state in which aggregate demand and tariffs are fixed at their 1995 values. The real exchange rate varies randomly during the initial periods following the AR(1) process estimated in the previous subsection. In the 31 years leading up to the estimation window, I then fix the exchange rate to follow its observed path.[14] I also assume that, during the initial periods, the plants are unaware of the tariff changes that start taking place in 1995, the first year of the simulation window. In 1995, they learn the tariff transition path

[14] I have real exchange rate data for the years 1964 to 2008 such that I can use the observations for the years 1964 to 1994 during the initialization period.

that leads to the new, low-tariff stochastic steady state. Real exchange rate and aggregate export demand follow their observed paths and plants form expectations according to the estimated processes. For more details on the numerical solution method for solving the plant problem and the global optimization algorithm used in finding the minimum of the objective function you may also consult Appendix E.

Table 4: Data moments used in estimation

Export revenue growth rate

Moment	Data	Model
Mean	0.051	0.056
Std	0.730	0.634
Skewness	0.002	0.061
Kurtosis	5.326	6.682
Autocorr(1)	-.1958	-.151
Autocorr(2)	-0.040	-0.086

Growth rates entrants

Period	Data	Model
1	0.276	0.281
2	0.062	0.127
3	0.063	0.065
4	0.041	0.028

Survival rates entrants

Period	Data	Model
0	0.667	0.643
1	0.826	0.760
2	0.877	0.847
3	0.902	0.903
4	0.923	0.935
5	0.922	0.950
6	0.936	0.960
7	0.949	0.968
8	0.960	0.967

Export revenue distribution

Quintile	Data	Model
2	0.006	0.002
3	0.019	0.008
4	0.060	0.043
5	0.915	0.946

Export participation

Moment	Data	Model
$Corr(Exp_t, Exp_{t-2})$	0.881	0.878
$Corr(Exp_t, Exp_{t-4})$	0.826	0.832
$NE - E$	0.056	0.052
$E - NE$	0.030	0.029
1995 Exporters	0.544	0.560

Note: The table reports the data moments that identify the model parameters via a Simulated Method of Moments estimation. They can be classified into five subcategories: 1) Statistics of the export revenue growth rate 2) Export revenue growth rates for entrants into exporting in the years after entry 3) Survival rates for entrants in the years after entry 4) Quintiles of the export revenue distribution 5) Moments on export participation, and transitions. Growth rates are calculated as $(x_t - x_{t-1})/(.5(x_t + x_{t-1}))$. This statistic is bounded between -2 (exit) and 2 (entry). Exp_t is an indicator variable that equals one if a plant has positive export revenue in period t and zero otherwise. Data refers to data moments. Model are simulated counterparts from the model's baseline specification. *Source:* FDZ der Statistischen Ämter des Bundes und der Länder, AFiD-Panel Industriebetriebe, 1995-2008, author's calculations.

I use a total of 28 moments from the AFiD data to estimate the model. See Table 4 for a summary. They can be devided into five broad categories. The first category contains moments of the export revenue growth distribution, the first four centered moments and one and two year autocorrelation. Revenue growth is again defined by $\frac{Rev_t - Rev_{t-1}}{.5(Rev_t + Rev_{t-1})}$ for it to include entry and exit. Export revenue growth rates for entrants in the first four years after entry constitute the second subcategory.[15] The third set of moments is made up of the survival rates for entrants into exporting after the initial year and the eight subsequent years. The fourth subcategory describes the export revenue distribution and contains the shares in total export revenue (averaged over the sample period) for the second to fifth quintile.[16] Finally, the last set of moments concerns the extensive margin of exporting:

[15] The growth rate in the year of entry is 2 by construction.

[16] The first quintile is linearly dependent on the other four quintiles and its inclusion into the estimation

persistence in exporting status over two and four years, average entry ($NE - E$) and exit ($E - NE$) rates into and from exporting as well as total export participation at the beginning of the sample.

5 Results

This section presents my estimation results. Table 5 reports the parameter estimates for the baseline model and for a version in which all accumulation of export specific demand has been shut down. Overall, the baseline model does a good job in matching the target moments and in accounting for the behavior of entrants into exporting in the year after entry. The model predicts an even larger growth in total exports than what is observed, even though the estimated price elasticity of demand in the export market of 1.42 is well within the low range commonly calibrated in open economy business cycle models. While both the baseline version and the restricted fixed costs version somewhat underpredict the growth in export participation towards the end of the sample, the baseline model clearly does a better job in replicating the data. Most importantly, while the fixed cost model predicts aggregate exports basically flat after 2002 in the absence of favorable macroeconomic shocks, the baseline model reproduces well the 50 percent surge between 2002 and 2008 as plants are still building up their foreign demand after the favorable shocks which occurred during the first half of the sample. Estimated entry costs of exporting are low compared with other estimates in the literature. It turns out, however, that by far the largest cost of exporting is spent on building up and maintaining a foreign demand base which constitutes a large sunk investment as well.

5.1 Parameter estimates

The second and third column of Table 5 report the estimated parameter vector $\hat{\theta}$ along with its 95 percent confidence interval for the model baseline specification. I also estimate a restricted model version with α set to zero which reduces the set-up to a pure fixed cost model like the one estimated in Das et al. (2007). This allows me to investigate in how far they differ in terms of predictive power and dynamic implications. Most parameters are fairly tightly estimated. I estimate a price elasticity of demand of 1.432.[17] With confidence bounds at 1.248 and 1.615, this estimate is unfortunately not very precise. Still, the estimation procedure puts the it well in the low range of about 0.9 to 2.0 typically calibrated in open economy macro models. At the same time it manages to account for the strong growth in average export revenue as result of the favorable shocks to the aggregate export environment.

would add no further information.

[17] An estimate of 1.432 for η implies a mark-up over marginal costs of 231 percent and a gross profit share in revenues of over 81 percent. One should keep in mind however, that an important part of German manufacturing exports constitute medium to high tech products and investment goods such that fixed operating and development costs make up an important part of overall costs. Also, these profits have to pay for entry and fixed costs of exporting and costs of accumulating and maintaining distribution channels which, as reported below, make up between 20 to 40 percent of revenues alone.

Table 5: Parameter estimates

	Baseline		**No customer capital**	
Parameter	Estimate	95% Conf. Int.	Estimate	95% Conf. Int.
Demand elasticity				
η	1.432	[1.248, 1.615]	3.472	[3.238, 3.706]
Foreign demand technology				
α	0.526	[0.508, 0.543]	–	–
δ	0.207	[0.191, 0.222]	–	–
Revenue productivity distribution				
ρ_ϕ	0.871	[0.862, 0.881]	0.992	[0.992, 0.992]
σ_ϕ	0.307	[0.303, 0.311]	0.369	[0.364, 0.373]
σ_χ	1.776	[1.704, 1.849]	3.346	[3.258, 3.343]
Costs of foreign demand accumulation				
c^{lin}	1.166	[0.994, 1.339]	–	–
c^{conv}	2.851	[2.448, 3.254]	–	–
Fixed costs of exporting				
γ_E	1.040	[0.990, 1.339]	1.679	[1.513, 1.844]
σ_E	0.347	[0.316, 0.379]	0.767	[0.679, 0.853]
γ_F	0.625	[0.582, 0.667]	0.610	[0.585, 0.634]
σ_F	1.241	[1.163, 1.319]	0.355	[0.310, 0.399]

Note: The table displays the estimated components of the parameter vector $\hat{\theta}$ along with the respective 95 percent confidence intervals. Columns two and three report results for the model baseline specification. The two rightmost columns reports results for a restricted model version in which I set α to zero such that firms do not accumulate export market specific demand. In consequence, the parameters δ, c^{lin}, c^{conv} are not part of the estimation either.

5.2 Identification

Table 10 in the appendix reports a stylized Jacobi matrix evaluated at the baseline estimate of the parameter vector. As one can see there, many of the above moments are affected by a large subset of the parameter vector such that the estimate of any parameter cannot be attributed to one moment alone. Here, I want to give some more intuition for what subset of moments identifies which parameter.

– **Parameters of the foreign demand technology** (α, δ)
  The curvature of the foreign demand technology has very strong positive effects on the autocorrelation of foreign revenue growth as well as on the growth rates for plants that newly enter into exporting. The higher α, the higher the target level of foreign demand and the longer the plant will show positive revenue growth after entry or after a positive productivity shock. This also means that the distribution of foreign revenue is more spread out and a larger share of total revenue is generated in the top quintile. Finally, α decreases transitions into and out of exporting by increasing persistence in exporting. In that sense, the accumulation of a demand base acts much like a sunk entry cost spread out over time. Depreciation δ in many ways has an opposing effect. Larger attrition rates for foreign sales relationships mean less of an incentive to invest into them and lower growth rates after entry. This also implies a

more compressed sales distribution. δ also decreases persistence in the export status and and increases transitions.

– **Demand elasticity** (η)
As mentioned above, the foreign demand elasticity is not estimated with a very strong precision. This also shows in the Jacobi matrix. η affects mean growth rate overall as well as for entrants.

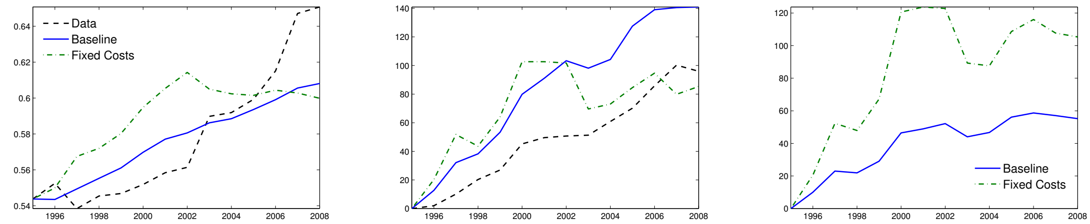
– **Costs of foreign demand accumulation** (c^{lin}, c^{con})
A higher proportional profit loss in building a foreign customer stock decreases growth rates for entrants and means a more compressed revenue distribution overall. Higher convex investment costs have plants spread out their investment over more years after entry or a positive productivity shock. They do, however, also decrease the value of investment overall which, evaluated at the baseline estimate, actually means lower growth rates in the years three and four after entry. Experimentation showed this effect to be non-monotonic throughout the larger parameter space.

– **Revenue productivity distribution** ($\rho_\phi, \sigma_\phi, \sigma_\chi$)
Both ρ_ϕ and σ_ϕ have effects on the centered moments of the overall growth rates and they both induce positive autocorrelation as productivity innovations become larger and more persistent. More persistent innovations in particular also mean higher growth rates for entrants as they can expect to stay productive for a longer time and accumulate more demand. Increases in all three parameters spread out the sales distribution. In some sense σ_χ picks up residual dispersion after α and the parameters of the revenue productivity process have been identified.

– **Fixed costs of exporting** ($\gamma_E, \sigma_E, \gamma_F, \sigma_F$)
Sunk entry and continuation costs have an impact on almost all aspects of the model. They increase the higher moments and autocorrelation of export revenue growth by introducing stronger selection on productivity in entering exports. They make exit more likely for entrants which reduces initial revenue growth. The more compressed revenue distribution is also a consequence of stronger selection and less export participation. Finally, a higher sunk component in fixed costs introduces more persistence in exporting, a fact that has been exploited in previous estimations of sunk cost models[18].
Higher variability in sunk and fixed costs in many ways has the opposite effect off a higher mean. It makes export participation more volatile thereby increasing exit and (re-)entry and decreasing persistence in exporting. Higher variance in entry costs means more firms are going to enter who are unlikely to survive long. More variable fixed costs increase exit probability for all firms and in consequence also for entrants. This introduces selection which means higher average growth rates for those entrants that survive.

[18] See for instance Roberts and Tybout (1997).

Figure 3: Export participation and total export revenue



(a) Export participation (b) Total exports (c) Q_t

Note: Panels (a) and (b) display export participation and the cumulative growth in total export revenues in the data sample used for estimating the model (Dash-dotted line) and compares it to the respective series in the baseline model (solid line) and the restricted model version (dashed line) where α is restricted to zero. Panel (c) displays a summary measure for aggregate export profitability, $Q_t \equiv D_t^W \left(\frac{RER_t}{1+\tau_t}\right)^\eta$, for the two model specifications.

Source: FDZ der Statistischen Ämter des Bundes und der Länder, AFiD-Panel Industriebetriebe, 1995-2008, author's calculations.

5.3 Model fit

Coming back to Table 4, the columns entitled $\mu(\hat{\theta})$ report the model generated moment vector evaluated at the baseline estimate $\hat{\theta}$ next to the target vector $\mu(\theta_0)$. Overall, the model provides a close fit to the data. Regarding the export revenue growth rate, the model reproduces the centered moments well and gets right the increase in one and two year autocorrelation, even though the increase is steeper in the data. Like in the data, entrants into exporting grow strongly in the years after entry and their survival probabilities are increasing in exporting tenure, though the data feature a step increase after the initial year, where the model produces a smoother profile in survival rates. The export revenue distribution in the model is more disperse than in the data and the model overestimates initial export participation.

5.4 Model comparison

I now want to turn to the question in how far the baseline model's implications differ from those of a model with stochastic sunk and fixed cost as only costs of exporting like the one estimated in Das et al. (2007). I therefore re-estimate the model setting α to zero and have $\delta, c^{lin}, c^{conv}$ take some arbitrary positive values. The parameter estimates of this restricted specification are reported in the two rightmost columns of Table 5. I then simulate the two estimated model versions for the duration of my estimation sample feeding in the observed series for aggregate tariffs, aggregate export demand and the real exchange rate and record the resulting series for aggregate export participation and cumulative growth in aggregate exports which were not specifically targeted in the estimation. The first two panels of Figure 3 compare the results to the data.

It follows from equation (2) that aggregate export revenue at time t in the model is given by

$$\frac{1}{\eta}\sum_{i=1}^{N} z_{it} D_{it}^{\alpha} D_t^W \left(\frac{RER_t}{1+\tau_t}\right)^\eta .$$

Let me now define $Q_t \equiv D_t^W \left(\frac{RER_t}{1+\tau_t}\right)^\eta$ as summary measure of aggregate export profitability which moves the incentive to enter/stay in exporting and to increase foreign market presence. Again normalizing the sample beginning in 1995 to zero, I plot the cumulative growth in aggregate export profitability for both model versions in the rightmost Panel (c) of Figure 3. While both series use the same aggregate price and demand series in their calculation, they differ due to the much higher elasticity of substitution η of 3.47 compared to only 1.43 in the baseline version. Both series experience a strong increase up to 2000 as tariffs drop and the German real exchange rate experiences a 20 percent depreciation vis-à-vis its trading partners. Afterwards the increase is much more subdued in case of the baseline model and even reversed to a degree as rising overall demand is counteracted by a rise in the real exchange rate of about 10 percent.

The much higher estimate for the demand elasticity η in the fixed cost model implies that aggregate exports are quite responsive to movements in the real exchange rate. This constitutes a version of what has previously been called the *elasticity puzzle* in international economics. In order to reconcile the high observed mean growth rate in plant export revenue in response to the favorable changes in the aggregate export environment at the time, export demand has to be relatively elastic.

The two model versions differ markedly in their implications for both export participation and total export growth. They both underpredict the rise in export participation at the end of the sample because they do not catch the growth spurt after 2005. They also do not catch the slight initial drop after 1996. Importantly, whereas the baseline model has export participation increase slowly after 1996, the fixed cost version predicts a steep increase which actually peaks in 2002 to then level off again. This is a consequence of the discussed strong sensitivity of aggregate export profitability to real exchange rate movements and clearly counterfactual to what is observed in the data.

Turning to the growth in aggregate exports, there is an important difference between the model versions. The baseline model predicts stronger growth, especially in the first six years, than is observed. Setting η a bit lower to a value still within confidence bounds moves the series closer to the data. It is however, a deficiency that it shares with the alternative specification. More importantly, the fixed cost model has aggregate exports pretty much flat after 2002 and even sees a decline which closely tracks the behavior of aggregate export profitability Q_t. Meanwhile, in the model with costly demand accumulation, export participation increases and firms slowly continue increasing their customer stock in reaction to the previous shocks. In consequence, aggregate exports rise by an additional 40 percent after 2003 which accords well with what we see in the data. As can one can also see in Figure 7, the baseline model matches the data well in another dimension by predicting the export expansion to be accompanied by a steady decline in exit rates whereas the fixed cost model predicts a rise in exit rates after 2002. The two models make similar predictions regarding entry.

5.5 Estimated Costs of Exporting

My structural approach allows me to quantify the size of sunk entry and continuation costs that plants face and the amount of resources they spend on maintaining and expanding their sales network. An estimate of 1.04 for γ_E implies that entry costs are on average .33 percent of the average plants export revenue in 1995 which translates into 33,467 1995 euros. Analogously, mean continuation costs are 20,108 1995 euros[19]. Compared with an entry cost estimate of between \$344,000 and \$412,000 in terms of 1986 dollars for a sample of Columbian manufacturing plants in Das et al. (2007), these estimates seem surprisingly low. It turns out that by far the largest share of sunk expenditures in exporting arises from costly investment into the customer network. As one may also see in Figure 8, during the time of the sample, the average exporter spends about 19 percent of export revenues on maintaining its customer base and between 8 and 19 percent on further expanding it. In 1995, the beginning of the sample, this translates into an average expenditure of 2.4 million euros on maintaining customer capital and a further 0.96 million on expanding it.

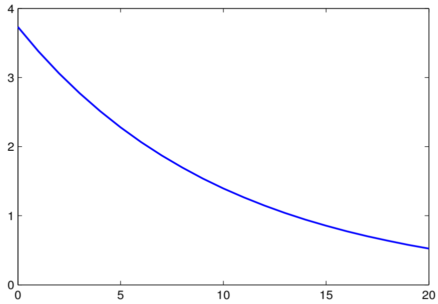
The low entry and fixed cost estimates are also well in line with the findings in Willis and Ruhl (2009) who, using the same data set as Das et al. (2007) to estimate a two-country heterogeneous firm model with endogenous export participation, find entry costs of \$104,242 in terms of 1986 dollars. This estimate drops by a factor of 8 when exogenously imposing the slow export revenue growth for new exporters. Their fix costs estimate of \$11,316 puts their results for the extended model version in the same ballpark as mine. There are as yet not many figures in the literature to which to compare the substantial estimates for money spent on marketing and maintaining and building a sales network. One exception is Arkolakis (2010) who reports that, depending on the definition used, American firms spend up to 7.7 percent of GDP on marketing activities. Taken together with the estimates presented here, this shows expenditures on building up demand, in the domestic or the foreign market, to be substantial and an important factor behind the slow revenue growth of plants after entering a market.

6 Macroeconomic Implications

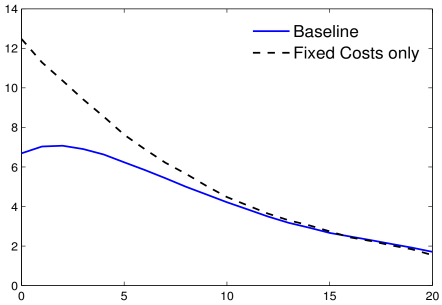
This section investigates the macroeconomic implications of introducing costly demand accumulation into a model of endogenous export participation. I trace out the effects of three kinds of shocks for the behavior of aggregate exports, export participation and entry and exit. First, I look at a persistent real exchange rate depreciation. Second, I introduce a permanent stochastic innovation to aggregate export demand. Finally, I consider the dynamic effects of moving the economy into a free-trade environment by removing all tariffs.

Figure 4: Dynamic response to a real exchange rate depreciation

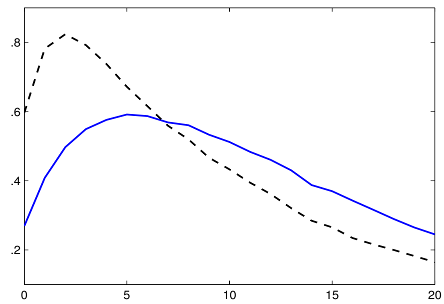
(a) Real exchange rate



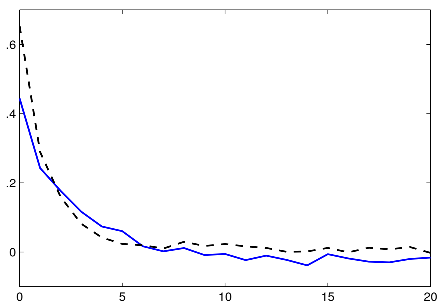
(b) Aggregate exports



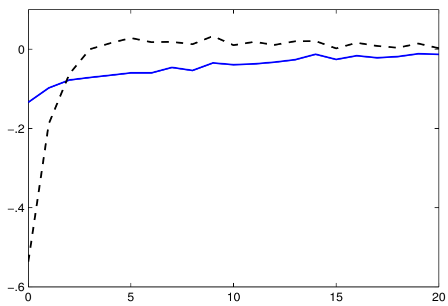
(c) Export participation



(d) Entry



(e) Exit



Note: This figure displays the dynamic response of aggregate exports, export participation and export entry and exit after a one standard deviation real exchange rate depreciation. The shock hits the economy in period zero and the graphs show the mean response in that year and the twenty years afterwards. The solid lines represent responses in the baseline model and the dashed lines represent the model with fixed entry and continuation costs only. The responses of real exchange rate and aggregate exports (Panel a and b) are in percentage deviations from steady state. The unit for participation, entry and exit (Panel c-e) is percentage point differences from steady state. Aggregate export demand is fixed at one. Tariffs are at the level of 1995.

6.1 Real exchange rate depreciation

Figure 4 displays the dynamic response of aggregate exports, export participation and export entry and exit to a one standard deviation real exchange rate depreciation. A first observation is that exports in the fixed cost model are much more responsive to the positive real exchange rate innovation than they are in the baseline version. The more than

[19] The stochastic nature of entry and continuation costs implies that average costs paid are lower. On average, plants pay about 15.923 1995 euros to enter into exporting and 19.077 euros to continue.

12 percent increase in aggregate exports translates into an elasticity of 3.4. That is more than 70 percent higher than the elasticity of 1.93 implied by the baseline estimate. Also, whereas exports in the fixed cost model follow the real exchange rate in monotonically reverting to their long-run mean, exports take until the second year after the shock to reach their maximum response when firms take time to react to the favorable conditions by investing into new sales relationships.

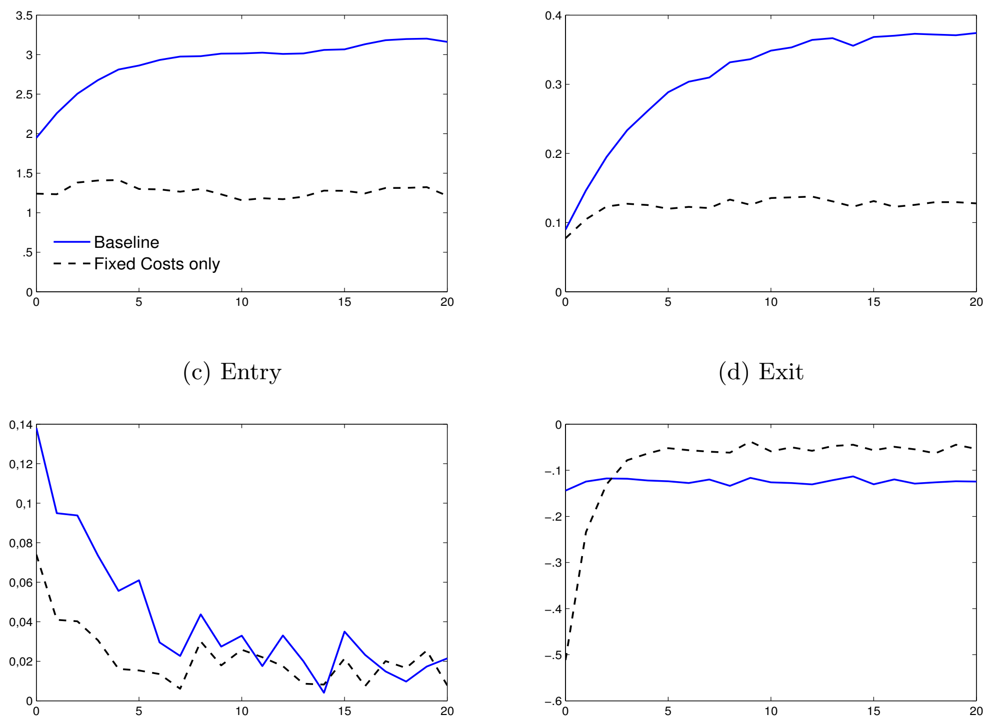
Export participation reacts stronger in the fixed cost model as well. This is the result of both a more pronounced increase in entry and a much steeper initial decline in exit from exporting. Nonetheless, the participation response in the baseline model turns out to be more persistent, because exit stays below average for much longer. As the exchange rate returns to its mean plants stop investing into the export market and let their additional sales relations slowly dissolve. Since that takes time, they remain less likely to exit for many years after the shock. This does not, however, make aggregate exports more persistent than in the fixed cost model since the effect is mostly on smaller firms.

6.2 Positive innovation to export demand

Figure 5: Dynamic response to persistent increase in export demand

(a) Aggregate exports (b) Export participation

(c) Entry (d) Exit



Note: This figure displays the dynamic response of aggregate exports, export participation and export entry and exit after a one standard deviation innovation to aggregate export demand. The shock hits the economy in period zero and the graphs show the mean response in that year and the twenty years afterwards. The solid lines represent responses in the baseline model and the dashed lines represent the model with fixed entry and continuation costs only. The response of aggregate exports (Panel a) is in percentage deviations from steady state. The unit for participation, entry and exit (Panel b-d) is percentage point differences from steady state. The real exchange rate is fixed at one. Tariffs are at their level of 1995.

Next, I look at the response to a positive innovation to aggregate export demand in Figure

5. In period zero, demand increases by 1.49 percent (one standard deviation) and stays at that level throughout the simulation. The real exchange rate remains fixed at its long-run average and tariffs are at the level of 1995. Again, the two models differ markedly in their behavior. Already the initial reaction of exports is much stronger in the baseline than it is in the restricted model, because firms immediately start building more market share. In the subsequent years, exports rise by another percentage point and it takes about five years for them to get there. While initially, participation in both cases increases by only .1 percent, this gain increases fourfold in the 10 years following the shock for the baseline case, but there is no comparable development in the fixed cost model.

The possibility to subsequently accumulate more demand increases the value of exporting more in the baseline model than it does in the fixed cost version as can be seen by an initial reaction in entry which is about twice as high. The explanation for the much larger increase in participation is similar to that for the more persistent reaction to the real exchange rate shock. Exit rates in the fixed cost model return to their mean two years after the positive innovation. They stay permanently lower in the baseline model. Larger idiosyncratic customer capital again implies a larger sunk investment in exporting and in consequence lower exit probabilities.

6.3 Moving to free trade

Finally, I consider moving the economy from its 1995 tariff level to free trade in Figure 6. This implies a 10 percent long-run gain in aggregate exports in the case of the baseline model and an 11.5 percent gain for the alternative version. Export participation rises by 1.13 and 1.00 percent in the long run respectively. While these numbers may seem rather small, one should keep in mind that with a trade-weighted average of 3.3 percent, tariffs were already quite low in 1995. The larger expansion in export participation in the baseline case again comes from a permanent drop in exit rates.

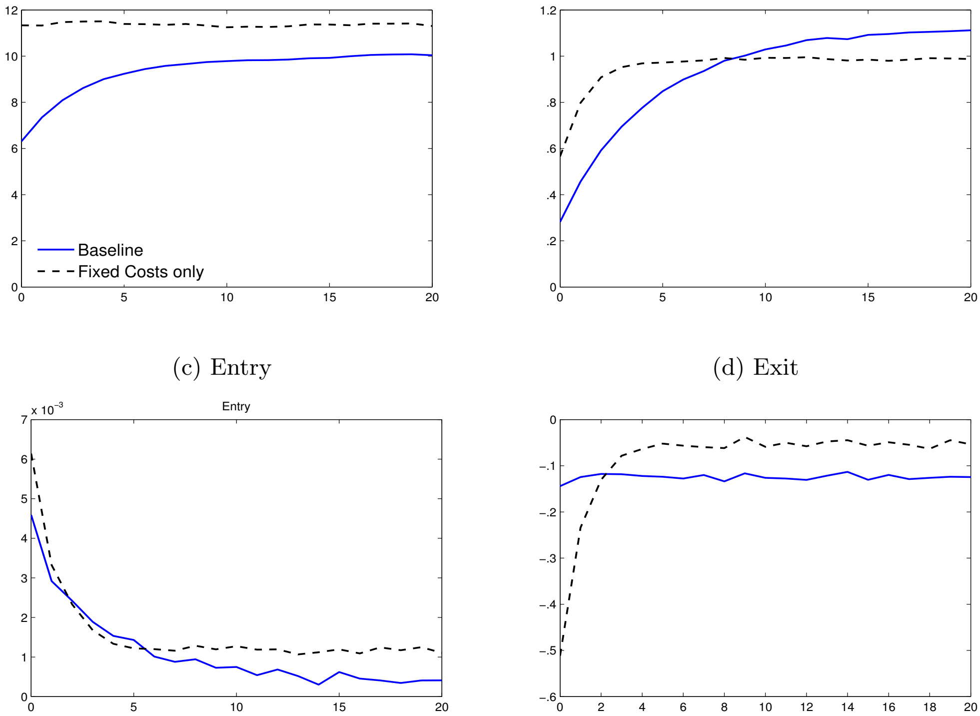
There are two important observations to make. First, as consequence of the demand friction that plants face when expanding export sales after the tariff drop the full realization of trade gains takes almost ten years. This is an important consideration to take into account when making welfare predictions about the reform. Second, both models predict long-run gains of similar size. Only the baseline model, however, is able to reconcile its prediction with a relatively low elasticity of exports to a real exchange rate depreciation as observed empirically. It therefore provides a solution to the elasticity puzzle in international economics by predicting both modest export reactions to real exchange rate movements and much larger gains after trade liberalizations.

7 Conclusion

In this paper, I introduce a capital theoretic concept of the customer stock into a dynamic structural model of export participation. I thereby contribute to a recent literature in

Figure 6: Dynamic response to trade liberalization

(a) Aggregate exports | (b) Export participation | (c) Entry | (d) Exit



Note: This figure displays the dynamic response of aggregate exports, export participation and export entry and exit after moving from the level of 1995 level of tariffs to free trade in period zero. The tariff reduction hits the plants unexpectedly in period zero. The solid lines represent responses in the baseline model and the dashed lines represent the model with fixed entry and continuation costs only. The response of aggregate exports (Panel a) is in percentage deviations from steady state. The unit for participation, entry and exit (Panel b-d) is percentage point differences from steady state. The real exchange rate and aggregate export demand are fixed at one.

the areas of macroeconomics and international trade which investigates the implications of slow demand accumulation for the propagation of aggregate shocks and the distribution of export participation and intensity across international destinations. The model builds on the framework introduced in Das et al. (2007) and extends it by the introduction of a decreasing returns to scale technology which converts an export market specific factor into export demand. Plants have to spend resources on acquiring this factor which I call *customer capital.* A plant starts every new exporting spell without any customer capital. In consequence, investments into export demand constitute a type of sunk cost which causes firms to be more reluctant to exit the market when faced with bad shocks. Adjustments to the customer capital stock are subject to convex adjustment costs such that entrants spread investments over several years until they reach their desired level. Just like physical capital, export demand depreciates in the absence of new investment as trade partners go out of business and brands lose salience with consumers. Maintaining and expanding the customer stock therefore imposes steady costs on exporters.

I structurally estimate the model on a panel data set of German manufacturing plants using a Simulated Method of Moments procedure. The data set spans the years 1995 to 2008, a time period that saw a strong increase in exporting activity among the plants in the sample. Export participation rose from 58 percent in the year 1995 to 66 percent in

2008 and total exports doubled in real terms. As consequence of the richness of the data set, I observe more than 14,000 export entry episodes in the sample. In the first four years of an export spell, plants display above average revenue growth rates and exit hazard rates are strongly declining with export tenure. These observations are consistent with a steady accumulation of export specific demand. While the entry into exporting is associated with strong growth in domestic revenues which hints at a positive productivity innovation, strong export revenue growth rates do not coincide with equally strong growth in the domestic market in the following years. This is an important indication that continued productivity growth is not responsible for the high export growth rate, at least insofar as productivity is not market specific.

I provide a first estimate of the costs related to export market demand accumulation. Estimated costs are substantial with plants on average having to spend between 26 and 38 percent of export revenues on maintaining and expanding their customer stock. On the other hand, estimated entry costs into exporting of 33,467 1995 euros are small compared to other estimates in the literature. The model fits the data well. Unlike a pure fixed cost model of export participation, it correctly predicts a strong growth in aggregate exports in the years after 2003 even though aggregate export profitability was flat in those years.

Regarding dynamic behavior, the model predicts total exports to keep expanding up to ten years after the hypothetical elimination of all tariffs for manufacturing exports. The total predicted rise in trade after eliminating an average of 3.3 percent ad valorem tariffs is 10 percent. This number is comparable in magnitude to the 11.5 percent a restricted alternative model without customer capital would predict. Unlike the fixed cost version, however, it is able to reconcile this prediction with a relatively subdued reaction of aggregate exports to real exchange rate movements. It therefore offers a possible answer to what has previously been called the *elasticity puzzle* in international economics - the discrepancy between high estimates for elasticities of substitution between goods from different countries from trade liberalization episodes and low estimates at business cycle frequency.

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A More information on the data set

Table 6: Summary statistics by sector

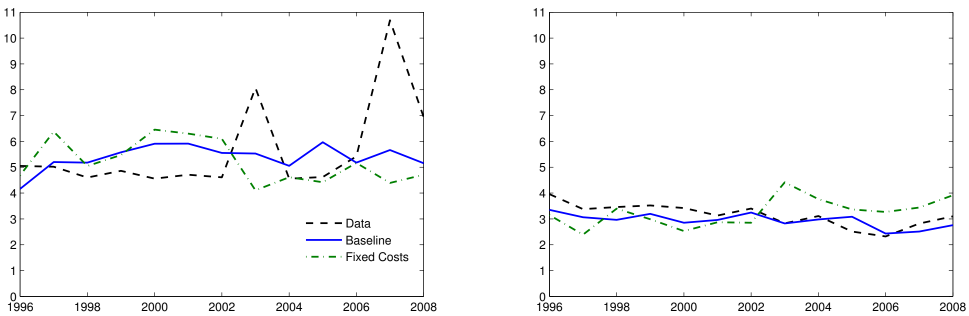
Sector (NACE rev. 1.1)	% of obs	Employment		Export	
		Mean	Total	Part. (%)	% in Rev.
Mining (10-14)	2.9	86	129,093	15.2	25.8
Food, Bev., Tobacco (15-16)	12.7	90	571,013	24.3	16.8
Textile, App. Leath (17-19)	4.7	96	226,591	71.7	23.2
Wood products (20)	4.1	57	115,840	39.4	17.1
Paper, Printing (21-22)	7.9	104	411,524	52.8	14.8
Chemicals (24)	3.5	268	480,703	81.1	34.4
Rubber, Plastics (25)	6.3	113	356,709	71.5	21.4
Non-metallic min. (26)	7.7	65	251,323	29.4	20.8
Metal, Metal prod. (27-28)	17	102	863,567	54.7	20.1
Machinery (29)	14	141	992,867	73.9	33.5
Electr. machinery (30-33)	11.4	152	871,488	60.1	30.4
Transport equip. (34-35)	3.1	569	908,038	66.3	26.0
Other manufacturing (36)	4.4	103	228,067	68.3	20.5

Note: The table displays summary statistics by sector for AFiD the sample of German manufacturing firms in 1999. Sectors are defined by broad NACE sectoral classifications. Statistics are the percentage of plant observations in the sector, average firm employment, total sectoral employment in the underlying population, export participation in percent and average share of exports in revenue for exporters. The 1999 sample contains a total of 50,154 plant observations.
Source: FDZ der Statistischen Ämter des Bundes und der Länder, AFiD-Panel Industriebetriebe, 1995-2008, author's calculations.

B Export entry and exit

Figure 7: Export transitions in the data and the two model specifications (1995-2008)

(a) Entry (b) Exit



Note: Panels (a) and (b) display export entry and exit rates in the data sample (dashed lines) used for estimating the model and compares it to the respective series in the baseline model (solid lines) and the restricted model version (dash-dotted lines) where α is restricted to zero.
Source: FDZ der Statistischen Ämter des Bundes und der Länder, AFiD-Panel Industriebetriebe, 1995-2008, author's calculations.

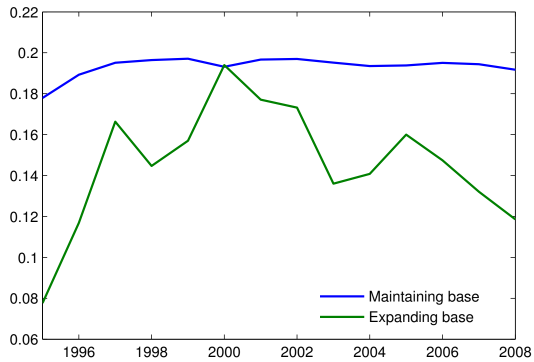
Table 7: Employment size distribution

Size class	% share	Employment Total	Employment Share (%)	Revenue (Billion 1999 €)	Revenue share (%)
1 to 49	52.82	723,667	11.2	84.6	7.1
50 to 99	21.56	757,004	11.7	101.8	8.5
100 to 249	15.83	1,232,709	19.1	191.8	16.0
250 to 499	5.76	992,980	15.4	169.5	14.1
500 to 999	2.58	871,948	13.5	195.7	16.3
Over 1000	1.45	1,857,817	28.9	452.9	37.9
Total	100	6,436,127	100	1,196	100

Note: The table displays the distribution of plants in the sample over 6 employment size classes for the year 1999. Columns (3) to (6) additionally report total employment, share in total employment, total revenue and share in total revenue for each size class.
Source: FDZ der Statistischen Ämter des Bundes und der Länder, AFiD-Panel Industriebetriebe, 1995-2008, author's calculations.

C Costs of customer capital accumulation

Figure 8: Average costs of demand base accumulation in terms of revenue



Note: The figure displays the average share of total export revenue that plants spent on maintaining and expanding their foreign customer base in a simulated version of the baseline model for the time of the sample (1995 to 2008) given the observed series for real exchange rates, export demand and tariffs.

D Aggregate variables

D.1 Tariffs

This section describes how I calculate the average tariff series used in simulating and estimating the model. The procedure consists of three steps. First, I calculate German manufacturing exports by year and by country using export data from the Eurostat Comext data base. I use those to identify the most important export destinations and to construct a stable aggregate "rest of the world" export market. Finally, I obtain disaggregated tariff data applicable to imports coming from the European Union for countries that are part of the aggregate. Weighting them by export volume (across destinations and within destinations across product lines) yields an average tariff measure.

The first challenge consists in identifying which export flows recorded in the trade data correspond to the sectors in my plant data base. The trade data are organized by the Harmonized System (HS) classification whereas sectors in the plant data are assigned based on the NACE rev. 1.1 classification. I match those sectoral classifications manually which requires some judgment based on the precise description of the sectoral definitions. I choose to construct matches between two digit NACE sectors and HS(2) chapters. Fortunately, in most cases identifying correspondences is relatively straightforward. Table 8 provides some examples.

Table 8: NACE to HS matches - examples

NACE rev. 1.1 sector		Matched HS(2) chapter	
16	Manufacture of tobacco products	24	Tobacco Manuf. Tobacco substitutes
21	Manufacture of pulp, paper, and paper products	47	Pulp of wood, waste & scrap of paper
		48	Paper & paperboard, articles of paper pulp
29	Manufacture of machinery and equipment n.e.c.	84	Nuclear reactors, boilers, machinery & mechanical appliances, computers
30	Manufacture of office machinery and computers		

Note: The table reports three three matches between the NACE (rev 1.1) sectoral classification and Harmonized System chapters that serve to construct an average tariff measure for German manufacturing exports between 1995 and 2008.

For the HS chapters identified as being manufacturing related, I then aggregate up exports and rank export destinations by export value for every year separately. The union set of the top twenty export destinations constitutes the world market for German manufacturing exports between 1995 and 2008. Table 9 lists the countries included and their share in total exports. Throughout the sample period, the aggregate stably accounts for 80 percent of total export volume.

For each member country I obtain six digit add valorem tariff data from the WTO. Exports to EU countries and to Switzerland are tariff free. I first compute tariff measures by country (value-weighted and unweighted) and then weight them again by export volume by year to obtain an aggregate series of for applicable tariff duties. Figure 9 displays the resulting series. The left panel displays the series used in the estimations, where value-weights are used in computing the tariff measures by country. The right panel is based on unweighted averages.

Table 9: Countries in world market aggregate

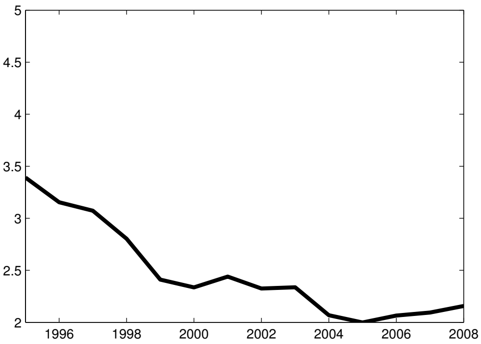
Country	Share in total exports (%)	
	1995	2008
Austria	5.49	5.51
Belgium[20]	6.49	5.10
Brazil	0.99	0.90
China	1.48	3.56
Czech Republic	1.63	2.84
Denmark	1.85	1.56
Finland	0.92	0.99
France	11.65	9.62
Hungary	.95	1.79
Italy	7.49	6.30
Japan	2.60	1.32
Netherlands	7.33	6.28
Poland	1.72	4.11
Portugal	0.87	0.84
Romania	0.35	0.91
Russia	1.38	3.28
South Korea	1.18	0.90
Spain	3.43	4.42
Sweden	2.45	2.06
Switzerland	5.41	3.88
Taiwan	1.01	0.50
Turkey	1.11	1.58
United States	7.60	7.42
United Kingdom	8.27	6.61
Total	80.56	79.15

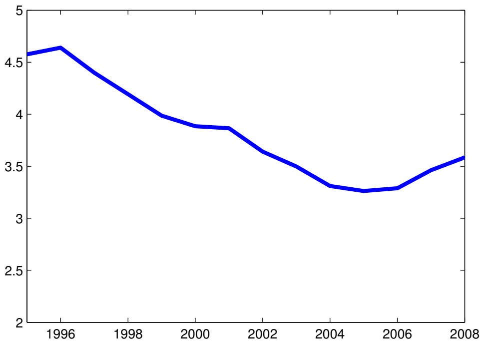
Note: The table reports the set of countries I use to calculate aggregate series for tariffs and export demand. I select them by ranking German manufacturing export destinations for every year between 1995 and 2008 by value. The set of countries is the union set of the top twenty destinations in every year.

Figure 9: Tariff series

(a) Trade-weighted average

(b) Unweighted average

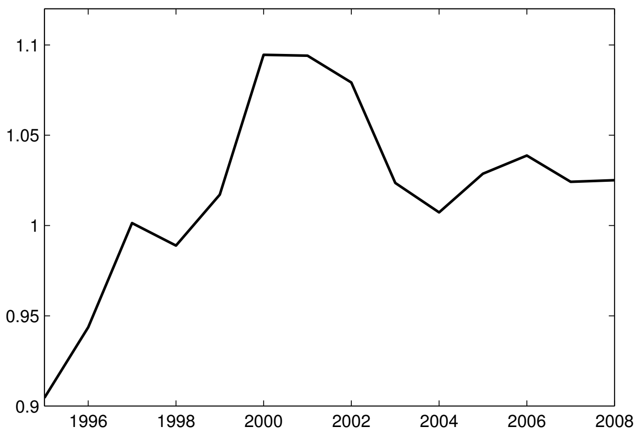




Note: The figure displays the average tariff series applicable to German manufacturing exports between 1995 and 2008. In the left panel, individual tariff lines have been value-weighted by their share in exports to some destination before weighting these averages by export value to destination. The right panel is based only on a value weighted average across countries. Individual tariff lines at some destination are not further weighted.

D.2 Real exchange rate

Figure 10: Real exchange rate series for Germany (1995-2008)



Note: The figure displays the trade-weighted real exchange rate for Germany between 1995 and 2008.

E Numerical Solution Method

This section of the appendix provides more details on the numerical solution algorithm. Source code for replication of the results will be available for download from the author's web page at `http://www.uni-bonn.de/~s6votjad/`. I carry out the calculations of the time series for aggregate tariffs and aggregate demand in Stata. The code for estimating the processes and generating the graphs in the paper are written in the MATLAB® language. Finally, the estimation algorithm is written in FORTRAN 90. The program makes use of the NAG Numerical Library for numerical integration and some statistical calculations. To greatly speed up the solution of the value function iteration, some of the main work is carried out on an NVIDIA Tesla GPU using the CUDA Fortran set of extensions to the FORTRAN language from PGI. For an exposition to the benefits of using graphics processors to solve dynamic program problems see Aldrich et al. (2011). For an introduction to programing in CUDA Fortran you should consult Ruetsch and Fatica (2011). For readers who wish to replicate the results without access to an NVIDIA card, there is a non-GPU version of the program available from the author upon request.

E.1 Simulated Method of Moments Procedure

In order to obtain parameter estimates, the problem consists of minimizing the quadratic form given by equation (5) in the parameter vector $\hat{\theta}$. $\hat{\theta}$ has twelve elements, many of them without reasonable prior guesses to start from. Equation (5) has no known derivatives and is not guaranteed to be continuous. It therefore employ a Particle Swarm global optimization algorithm. This method tries to improve on a set of candidate solutions, called particles, by randomly moving them around the search-space where the size of changes depends on the particle's position and velocity. Movements are also guided by the global and local memory of the best solutions visited so far[21]. Upon convergence to the global minimum, the variance-covariance matrix of the estimate is given by equation (6), where $E_0 \frac{\partial \mu}{\partial \theta}$ is again calculated using numerical differentiation.

E.2 Value Function Iteration

During the estimation procedure, for any given set of parameters θ, firm policies for export participation and customer capital investment solve the dynamic programming problem described by equations (3) and (4). I approximate the continuous variables D, ϕ, χ, RER and D^W using discrete sets of grid points. I then iterate on equations (3) and (4) until convergence.

The customer capital grid is equi-spaced in $\log(D)$ with an upper bound of ωD_{stat}^{max}, where $D_{stat}^{max} = \left(\alpha \left(RER^{max}/\tau^{low}\right)^{\eta} DW^{max} \phi^{max} \chi^{max} \delta^{-1}\right)^{\frac{1}{1-\alpha}}$ is the optimal customer stock choice in the absence of uncertainty and convex adjustment costs evaluated at the largest grid points of the aggregate and idiosyncratic state variables and ω is a fixed fraction. Experimentation yielded $\omega = 0.6$ as a suitable choice for D_{stat}^{max} never to be a binding constraint on plant choices. In discretizing the AR(1)-processes for the persistent component of idiosyncratic revenue productivity ϕ and the real exchange rate RER, I use Tauchen (1986). The grid points for the permanent component of idiosyncratic productivity $\log(\chi)$ are the mean values of a set of equi-likely bins of the normal distribution $N(0, \sigma_\chi)$. Finally, in discretizing the bounded random walk for $\log(D^W)$, I use an equi-distant set of grid points and obtain transition probabilities from a mixture of linear interpolation and Gaussian quadrature. During the estimation procedure I use 160 grid points for D , 10 grid points for ϕ and χ each, 7 grid points for RER and 5 grid points for D^w.

[21] For an introduction to the method see Poli (2008). For a description of the algorithm I employ, you may also consult `http://www.nag.co.uk/numeric/fl/nagdoc_fl23/xhtml/E05/e05saf.xml`.

Export participation policies take the form of threshold realizations $\hat{\xi}^E$ and $\hat{\xi}^F$and are therefore straightforward to calculate. The large dispersion in export revenues across plants in the data implies that customer capital policies span a large interval in $\mathbb{R}_0^+$. The challenge then consists of finding an accurate solution using only a relatively small number of grid points. Instead of optimizing over the discrete set of grid points, I use a golden section search optimization algorithm coupled with cubic spline interpolation of the value function[22].

The solution of the plant problem itself is subdivided into three steps. First, I solve for plant policies for the stochastic steady state that persists after 2008 in which tariffs are at a permanently low level. I then iterate backwards from 2008 to 1995 using the tariff series calculated in Section 3.4. Plants perfectly forecast the tariff series and they form expectations over $D_{t+1}^W$and RER_{t+1} given their estimated stochastic processes. Finally, I calculate policies that persist during the initial stochastic steady state ante 1995 in which plants are ignorant of the tariff changes that will start taking place in that year.

E.3 Transition Simulation

The policy functions that solve the plant's dynamic problem serve as input into $S = 20$ Monte Carlo Simulations with $N = 50,000$ plants each. During the iterations over different parameter guesses, the random draws are fixed to assure convergence of the global minimization algorithm. The simulation consists of 150 initial periods during which global demand is fixed and tariffs are at their high initial level and of the transition period lasting 14 years between 1995 and 2008. I do not limit plant choices regarding D to be on-grid and evaluate them using spline interpolation. Policy functions for export entry and continuation policy I interpolate linearly. During the transition period, when I feed in observed realizations for export demand D^W and the real exchange rate RER , I first linearly interpolate policies in these two dimensions. The estimated parameter vector $\mu(\theta)$ is the average over the S simulations

E.4 Stylized Jacobi matrix

[22] For an introduction to the calculation and use of splines in numerical analysis you may consult de Boor (1978). In calculating spline coefficients, I also make use of two routines that come as open source code with that book. They are available for download at `http://orion.math.iastate.edu/burkardt/f_src/f_src.html`.

Table 10: Stylized Jacobi matrix at baseline estimate

	η	α	δ	ρ_ϕ	σ_ϕ	σ_χ	c^{lin}	c^{conv}	γ_E	σ_E	γ_F	σ_F
$Mean\left(\frac{\Delta R_t}{R_t}\right)$	+	+	o	−	-	o	o	o	o	o	o	o
$Std\left(\frac{\Delta R_t}{R_t}\right)$	o	-	+	o	+	o	o	o	−	+	-	+
$Skew\left(\frac{\Delta R_t}{R_t}\right)$	o	++	+	−	-	+	+	+	++	−	++	−
$Kurtosis\left(\frac{\Delta R_t}{R_t}\right)$	o	o	-	-	−	o	o	o	++	-	+	-
$Autocorr(1)$	o	++	o	++	++	o	o	o	++	−	++	−
$Autocorr(2)$	o	++	-	++	++	-	-	-	++	−	+	−
$GRE(1)$	o	++	o	++	o	o	o	o	-	+	o	+
$GRE(2)$	o	++	-	++	-	o	-	+	−	+	−	+
$GRE(3)$	+	++	-	++	++	-	-	-	−	++	−	++
$GRE(4)$	-	-	−	++	−	−	−	-	−	+	−	++
$SR(0)$	o	o	o	o	o	o	o	o	++	-	o	-
$SR(1)$	o	o	o	o	o	o	o	o	+	-	+	-
$SR(2)$	+	o	o	o	o	o	o	o	+	-	+	-
$SR(3)$	o	o	o	+	o	o	o	o	+	-	+	-
$SR(4)$	o	o	o	+	o	o	o	o	o	o	o	-
$SR(5)$	o	o	o	o	o	o	o	o	o	o	o	o
$SR(6)$	o	o	o	o	o	o	o	o	o	o	o	o
$SR(7)$	o	o	o	o	o	o	o	o	o	o	o	o
$SR(8)$	o	o	o	o	o	o	o	o	o	o	o	o
$Q2$	o	−	+	−	−	−	+	+	+	-	+	-
$Q3$	o	−	+	−	-	−	+	o	+	-	+	-
$Q4$	o	−	+	−	-	−	o	o	+	-	+	-
$Q5$	o	+	o	o	o	o	o	o	o	o	o	o
$NE-E$	o	−	+	-	o	-	o	o	−	++	−	++
$E-NE$	o	−	+	o	o	-	+	o	−	++	−	++
$Corr(Exp_t, Exp_{t-2})$	o	o	o	o	o	o	o	o	+	-	o	-
$Corr(Exp_t, Exp_{t-4})$	o	+	o	o	o	o	o	o	+	-	+	-
$Exp95$	o	o	-	+	o	o	o	o	-	o	-	o

Note: The table displays a stylized version of the Jacoby matrix evaluated at the baseline estimate of the model. The Jacoby matrix provides a good guide as to what elements of the moment vector μ are strongly affected by any given parameter and in turn, help identifying this parameter. – signifies an estimated elasticity of below -1 (strong negative effect), - means an estimated elasticity between -1 and -.2 (negative effect). o marks no important effect (though entries are scarcely zero). + represents an estimated elasticity of between .2 and 1 (positive effect). All elastiticies larger than 1 are marked by ++.