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THE DYNAMIC EFFECTS OF CURRENCY UNION ON TRADE

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**ABSTRACT**

A currency union's ability to increase international trade is one of the most debated questions in international macroeconomics. This paper studies the dynamics of these trade effects. First, an empirical study of the European Monetary Union finds that the extensive margin of trade (entry of new firms or goods) responds several years ahead of overall trade volume. This implies that the intensive margin (previously traded goods) falls in the run-up to EMU. The paper's theoretical contribution is to study the announcement of a future monetary union as a news shock to trade costs in the context of a dynamic stochastic general equilibrium trade model. Early entry of new firms in anticipation is explainable as a rational forward-looking response under certain conditions, where essential elements include sunk costs of exporting and heterogeneity among firms of a type known before entry. The findings help identify which types of trading frictions are reduced by a currency union. The important role of expectations also indicates that continued gains from EMU depend upon long-term credibility of the union.

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## 1. Introduction

A currency union's ability to increase international trade has been one of the most debated questions in international macroeconomics, especially since Rose (2000) found potentially large effects in historical monetary unions. Subsequent literature with improved methodology and expanded data, including coverage of the European Monetary Union, has mostly supported the statistical significance of this effect, but estimated lower magnitudes.<sup>1</sup> Previous work has also documented that a substantial portion of the trade effect operates at the extensive margin, that is, trade of goods not previously traded.<sup>2</sup> A question that remains elusive is the mechanism by which a currency union affects trade. In order to help address this question, this paper studies the dynamics of these trade effects. It identifies new stylized facts about the timing of effects at the various margins of trade.<sup>3</sup> Then by constructing and simulating a dynamic "new" trade model augmented with news shocks, the paper draws implications regarding what types of trade cost reductions would be consistent with the observed dynamics.<sup>4</sup>

As motivation, the paper presents a new stylized fact in trade data regarding the effects of European Monetary Union (EMU). Based on disaggregated trade data the paper constructs measures of the extensive margin of trade (the entry of new goods categories) and the intensive margin (the amount of trade in previously traded goods categories). Panel regressions are used

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<sup>1</sup> There is an extensive literature on this subject. For a sampling of supporting evidence see Rose and Wincoop (2001), Glick and Rose (2002), and Frankel and Rose (2002). For critiques hostile to this view see Persson (2001), Nitsch (2002), and Baldwin (2006). For empirical studies of the European Monetary Union, see Micco, Stein, and Ordonez (2003), Baldwin and di Nino (2006), Flam and Nordstrom (2006), Berthou and Fontagne (2008), and Frankel 2010. Estimates for the effect on trade in the EMU range from 5% to 20%.

<sup>2</sup> Papers studying the effect of EMU on the extensive margin of trade, including Baldwin and di Nino (2006), Flam and Nordstrom (2006), and Berthou and Fontagne (2008), estimate a rise in the extensive margin in the range of 6% to 19%.

<sup>3</sup> While Micco, Stein and Ordonez (2003) consider the timing of overall trade effects, finding that effects begin in 1998, they do not consider the extensive margin. While Flam and Nordstrom(2006) measure the extensive margin for years prior to EMU, their objective is to compare the pre-EMU (1995-1998) period to post-EMU (2002-2005), taking the earlier period as a benchmark rather than considering the possibility that these early periods could themselves show an increase in the extensive margin.

<sup>4</sup> For influential examples of models of this type, see Ghironi and Melitz (2005), Ghironi and Melitz (2007), and Ruhl (2008), and Atkeson and Burstein (2008).

to identify the effect of adopting EMU on these two margins of trade, where dummies are used to indicate effects in years both before and after actual EMU adoption. Estimates indicate that the extensive margin began to rise already four years ahead of actual EMU adoption. While initial increases in the extensive margin are small, they are found to be very significant statistically, and to grow gradually over time to reach a maximum 3 years after EMU adoption. These dynamics contrast sharply with the dynamics of overall trade, where effects become significant much later (around one year prior to EMU adoption), with magnitudes that initially are much smaller than the extensive margin. This implies that the intensive margin, the difference between overall trade and the extensive margin, is negative in the run-up to EMU adoption. This effect dies out several years after adoption, as the extensive margin effect declines over time and the overall trade effect catches up.

It is striking that new goods appear to enter the export market before the monetary union actually generates an increase in trade. Some previous papers have discussed the need for dynamics to account for gradual adjustment to new trade opportunities, such as time to build to generate a sluggish response of new entry. But the evidence here is the opposite; rather than being sluggish, entry instead anticipates the future trade opportunities created by EMU. It is true that EMU did not become certain until a year before adoption, with announcement in 1998 of those countries satisfying the convergence criteria. However, when firms respond to shifts in expectations, the future profit opportunities need not be known with certainty; a simple shift in probabilities of uncertain events can induce changes in firm decisions. Exporting may well involve one-time sunk costs, such as one-time investment in distribution networks abroad. Given that paying a sunk cost presents the opportunity but not the requirement to sell abroad, the option value of establishing a presence in foreign market could become justified based upon rising probabilities of states of nature where exporting is profitable, even if these states are not

realized in the end. These facts suggest a need for trade models augmented with expectations and forward looking behavior in response to news about the future.

The theoretical contribution of the paper is to construct a trade model to understand the role of news shocks and shifts in expectations. We believe it is the first of the “new” dynamic trade models with firm heterogeneity to study the role of news shocks. The model focuses on real variables and abstracts from money and nominal exchange rates. Because the countries joining the European Monetary Union previously belonged to a system of mutually fixed exchange rates, EMU is not associated with a significant reduction in exchange rate volatility, or a significant change in monetary policy rules or shocks. Instead the model studies the adoption of a common currency as the elimination of trade costs of various types, frictions associated with currency conversion or other reduction in the significance of national borders. The model studies the effect of a news shock, whereby an announcement is made about a future reduction in these trade costs. These trade frictions can take one of several forms in the model: iceberg trade costs proportional to trade volume, fixed costs paid each period, and a one-time sunk cost. The model differs from Ghironi and Melitz (2005) and most models in the literature in assuming a distinct sunk cost for exporting, which is necessary for the extensive margin to respond to a news shock.

The first theoretical finding is that the anticipation effect of monetary unions on the extensive margin can be explained as rational forward-looking behavior, but it requires sunk costs and firm heterogeneity of a particular type. The key is heterogeneity in the present value of anticipated future profits of firms. Standard models of heterogeneity in terms of firm marginal costs realized after entry (as in the canonical model of Ghironi and Melitz, 2005) turn out not to satisfy this condition, nor does a simple model of learning by doing. What does work is heterogeneity in the sunk costs of entry, capturing the fact that some types of goods are harder to introduce into new markets than others. This may reflect more extensive distribution

networks or more demanding product standards required for some types of goods. Without this feature, firms contemplating entry in periods prior to the monetary union adoption correctly anticipate that entry of firms in the future period of adoption will compete away profits in excess of the sunk cost, eliminating the incentive for early entry. However, heterogeneity in terms of the size of the sunk costs of entry will imply that profits per firm will remain at a higher level after the adoption, equal to the sunk cost of the marginal exporter. If firms with high productivity or lower entry costs know this prior to making the entry decision, this implies an expectation for future profits in excess of sunk costs, thereby justifying their early entry. The model also studies an experiment using a second-order approximation to show that this entry in anticipation of future monetary union is robust to moderate levels of uncertainty about the future.

A second theoretical finding is that the model also points to iceberg costs as the key trade costs reduced by the monetary union adoption. A news shock reducing the sunk cost itself leads to an exit of firms prior to adoption rather than the observed entry. Further, a news shock reducing the fixed cost of trade fails to generate the observed rise in overall export volume upon adoption.

Third, the finding that the extensive margin anticipates adoption suggests that a significant portion of the welfare gains of adopting a monetary union, which work through love of variety in utility, rely upon expectations of a monetary union and precede its actual adoption. This indicates that continued gains from a monetary union rely upon expectations for the union's continued existence in the long run; an expectation of future union dissolution would reduce the welfare gains.

The next section of the paper discusses the empirical methodology and new stylized facts. Section three defines the model, and section four discusses the simulation results.

## 2. Empirical Motivation

The study uses a panel dataset which covers exports at an annual frequency from 1973 to 2004. The trade data of 1973-2000 come from the NBER-UN World Trade Data set, developed by Rob Feenstra and Robert Lipsey, documented in Feenstra et al. (2005). The trade data after 2000 come from the UN Comtrade Data set, developed as the same way as in Feenstra et al. (2005). This data set computes annual bilateral trade flows at the four-digit Standard International Trade Classification, by performing a series of adjustments on UN trade data<sup>5</sup>.

Following Hummels and Klenow (2005), the extensive margin is measured in a manner consistent with consumer price theory by adapting the methodology in Feenstra (1994).

The extensive margin of exports from country  $j$  to  $m$ , denoted by  $EM_m^j$ , is defined as

$$EM_m^j = \frac{\sum_{i \in I_m^j} X_{m,i}^W}{X_m^W} \quad (1)$$

where  $X_{m,i}^W$  is the export value from the world to country  $m$  of category  $i$ .  $I_m^j$  is the set of observable categories in which country  $j$  has positive exports to country  $m$ , and  $X_m^W$  is the aggregate value of world exports to country  $m$ . The extensive margin is a weighted count of  $j$ 's categories relative to all categories exported to  $m$ , where the categories are weighted by their importance in world's exports to country  $m$ .

The corresponding intensive margin of exports from country  $j$  to  $m$ , denoted as  $IM_m^j$  is defined as

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<sup>5</sup> It is noted that the data purchased from the UN for 1984-2000 only had values in excess of \$100,000, for each bilateral flow. To be consistent, the cutoff of exports in this study is set as \$100,000, which implies that goods are considered nontradable if an export value of the category is less than \$100,000.

$$IM_m^j = \frac{X_m^j}{\sum_{i \in I_m^j} X_{m,i}^W} \quad (2)$$

where  $X_m^j$  is the total export value from country  $j$  to country  $m$ . The intensive margin is measured as  $j$ 's export value relative to the weighted categories in which country  $j$  exports to country  $m$ . Therefore, multiplying the intensive margin by the extensive margin can get country  $j$ 's share of world exports to country  $m$ ,  $EXShare_m^j$ :

$$EXShare_m^j = \frac{X_m^j}{X_m^W} = EM_m^j IM_m^j \quad (3)$$

The categories of goods exported might differ across exporters and change over time. With the same level of share of world exports to country  $m$  at time  $t$ , the measurement implies that country  $j$  would have a higher extensive margin measure if it exports many different categories of products to country  $m$ , whereas, it would have a higher intensive margin if country  $j$  only export a few categories to country  $m$ .

Separate panel regressions are run by regressing in turn the extensive margin, the intensive margin, and the exporter's total share on the currency union status as well as controls. Controls include membership in the European Union, which entailed economic reforms that could be expected to raise bilateral trade themselves, as well as the standard set of variables representing country size and distance used in gravity trade models to explain bilateral trade. The benchmark regressions take the form:

$$Y_{jm,t} = \beta_0 + \beta_1 EMU_{jm,t} + \beta_2 EU_{jm,t} + \beta_3 EUTrend_{jm,t} + \lambda X_{jm,t} + \gamma F_{jm,t} + \phi t + \kappa EX + \omega IM + \varepsilon_{jm,t} \quad (4)$$

The model is estimated by ordinary least squares with robust standard errors clustered in export pair level, where  $j$  is the exporter and  $m$  is the importer. The dependent variables ( $Y_{jm,t}$ ) will be either the logarithm of country  $j$ 's extensive margin of exports to country  $m$ , the logarithm of country  $j$ 's intensive margin, or the logarithm of share of world exports. Regressors include



dummies for the currency union status,  $EMU_{jm,t}$ . A dummy for the European Union,  $EU_{jm,t}$ , is included to control the impact of a free trade area on export. However, the European Union may become a deeper agreement and increase the impacts over time, so  $EUTrend_{jm,t}$  is included to control the EU effects on export through time. The regressor  $X_{jm,t}$  is a set of variables that vary over time, which includes the logarithm of real GDP per capita of exporter  $j$  relative to real GDP per capita of all countries who export to importer  $m$ , logarithm of exporter  $j$ 's population relative to real GDP per capita of all countries who export to importer  $m$ , and a dummy variable indicating whether the two countries had a free trade agreement at time  $t$ .  $F_{jm}$  is a set of variables that do not vary over time, such as the logarithm of distance between country  $j$  and  $m$ , a common language dummy, a land border dummy. Also included is a time effect,  $t$ , to control for time-specific factors such as global shocks or business cycles.

To avoid omitting variables that may affect bilateral trade, two vectors of dummy variables,  $EX$  and  $IM$ , are included indicating exporter and importer fixed effects. As Anderson and van Wincoop (2003) proposed, country effects are included as controls for multilateral resistance. We decided to use separate country fixed effects for each country as exporter and importer, because in contrast with the related literature on trade flows, our dependent variable specifies the direction of trade.

We begin by reporting result for a sample of 15 European countries, including 3 countries which are not members of the monetary union.<sup>6</sup> Initial results using country fixed effects are reported in the first three columns of Table 1. Joining EMU raised overall exports by 11.9%, which is smaller than the effects originally found by Rose but similar to those found by other

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<sup>6</sup> The countries included are Austria, Belgium-Luxembourg, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Netherlands, Portugal, Spain, Sweden, and United Kingdom. Ten of these joined the monetary union in 1999, and Greece joined in 2001. Denmark, Sweden, and United Kingdom did not join the monetary union.

researchers focusing on a European sample.<sup>7</sup> The effect is slightly smaller in magnitude than the effect of entry into the EU. The first column indicates that the majority of this trade effect occurs at the extensive margin, which rises by 6.3%. In fact, while the effect at the extensive margin is statistically significant, that at the intensive margin is not. This result emphasizes the importance of the extensive margin for understanding the trade effects of monetary unions. The remaining columns confirm that this result is robust to alternative sets of controls, such as country-year fixed effects to control for time-varying multilateral resistance in the determination of the trade pattern, and country-pair fixed effects to control for the bilateral tendency to trade instead of the multilateral resistance.

Table 2 reports result regarding the dynamics of these trade effects over time. The regression equation is augmented with leads and lags of the EMU indicator variable, to capture the effects of EMU before and after adoption.

$$Y_{jm,t} = \beta_0 + \sum_{s=-3}^5 \beta_{1,s} EMU_{jm,t+s} + \beta_2 EU_{jm,t} + \beta_3 EUTrend_{jm,t} + \lambda X_{jm,t} + \gamma F_{jm,t} + \phi t + \kappa EX + \omega IM + \varepsilon_{jm,t} \quad (4')$$

The main finding is that the extensive margin rises well ahead of the actual adoption of the monetary union. All three sets of estimations agree on this point, all showing a statistically significant positive coefficient on all leads of the EMU indicator in their respective extensive margin regressions. The magnitudes of this effect are similar to those found in table 1, tending to be somewhat smaller in years prior to EMU, and larger in years following actual adoption of EMU. The three sets of estimations vary among themselves regarding values of other coefficients. Overall trade rises one year ahead of EMU adoption under country fixed effects and country-pair fixed effects; trade rises earlier under country-pair fixed effects. The intensive margin is either insignificantly different from zero or negative in the run-up to EMU depending

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<sup>7</sup> The export share is 1.119 times higher (11.9%) because  $\exp(0.112) = 1.119$ ; the extensive margin is 1.063 (6.3%) because  $\exp(0.061) = 1.063$ .

on the estimation, but tends to become significantly positive several years following implementation.

In order to get more precise estimates, we follow Frankel (2010) in expanding the data set to all available countries. The full country sample covers 148 countries after combining all the data sets<sup>8</sup>, so we include all of these in the gravity regression above. We augment the regression equation with an additional indicator variable to control for currency unions other than EMU. Consequently, the EMU indicator variables remain specific to the monetary union in Europe, and the coefficients on these indicators can continue to be interpreted as the effect EMU.

Results are reported in Table 3. The additional data produce highly significant parameter estimates both for estimations using country fixed effects and country-year fixed effects, and there is a close correspondence in results between these two cases. We will focus on results for the latter estimation, as this controls for time-varying multilateral resistance, which past literature has emphasized as a potential source of bias. In contrast, estimates from using country pair fixed effects lack statistical significance. Country-pair fixed effects could be useful if trade resistance is bilateral rather than multilateral in nature. However, it eliminates cross-sectional variation in the panel and leaves only time-series variation. Given that the vast majority of the new countries added to this larger sample have not entered or left a currency union during this sample period, these additional countries yield no information in the estimate. See Bergin and Lin (2009) for a discussion of this point.

Figure 1 plots the regression coefficients arising from the time-varying fixed effects estimation. Estimates agree with the main conclusion of Table 2, showing a significant rise in

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<sup>8</sup> Data on world trade flows come from the NBER-UN World Trade data set. Data on real GDP and population come from the World Bank's World Development Indicators. Geographical, distance, and historical information come from Rose's (2004) data set.

the extensive margin in anticipation of EMU adoption, but estimates here offer greater precision and details about the dynamics. The extensive margin effect can now be seen to rise smoothly and gradually over time. Estimates are small and insignificantly different from zero for initial years, but the effect becomes significant starting four years prior to EMU adoption. This contrasts with the overall effect on trade, which does not become significant until much later, one or two years before EMU adoption depending on the criterion for significance. The magnitude of the extensive margin effect in these periods is also much larger than that on overall trade. This implies that the effect on the intensive margin of trade, the difference between overall and extensive margin, is actually negative. We can confirm that the difference between the two is statically significant, as Column 8 of Table 3 reports coefficients in the intensive margin regression, and shows that EMU dummies are significantly negative for all periods preceding EMU adoption.

The figure also shows that the dynamics change after EMU adoption. The extensive margin effect reaches its maximum about 3 years after adoption, and then falls in remaining years. At this point the overall trade effect nearly catches up with the extensive margin. Overall trade and the extensive margin rise 44% and 55% respectively. This is larger than the estimates from the European country sample in Table 2, though still much smaller than estimates of currency union effects from the work of Rose. These larger values do correspond with those found in Frankel (2010), which argued that an expanded data set, in terms of time and countries, is helpful in detecting EMU effects. The narrowing of the difference between extensive margin and overall trade after EMU adoption is confirmed by the fact that the intensive margin coefficients are no longer significantly negative.

It is striking that new goods appear to enter the export market before the monetary union actually generates an increase in trade. Why would firms enter a market when a constant level of trade must be divided among more firms, presumably leading to a fall in profits? Given

that trade does eventually rise, this entry would seem to indicate forward looking behavior on the part of firms, in response to news about future policy changes and rise in opportunities for trade. Such anticipation effects cannot be explained in the context of a standard static trade model, where trade and entry occur simultaneously. Some previous papers have discussed the need for dynamics to account for gradual adjustment to new trade opportunities, such as time to build to generate a sluggish response of new entry. But the evidence here is the opposite; rather than being sluggish, entry instead anticipates the future trade opportunities. These facts suggest the need for trade models augmented with expectations and forward looking behavior in response to news about the future.<sup>9</sup>

### **3. Benchmark Theoretical Model**

Consider a model of two symmetric countries, home and foreign, which trade with each other. Engaging in trade involves paying several types of trade costs: iceberg costs, fixed costs each period, and a one-time sunk cost. The model differs from Ghironi and Melitz (2005) and most models in the literature in assuming a distinct sunk cost for exporting.<sup>10</sup> The ability to generate an anticipation effect in the extensive margin in response to a news shock depends upon a sunk cost associated with exports.

Although the model is motivated by study of a monetary union, the model focuses on real variables and abstracts from money and nominal exchange rates. Because the countries joining the European Monetary Union previously belonged to a system of mutually fixed exchange rates, EMU is not associated with a reduction in exchange rate volatility, or any significant change in monetary policy rules or shocks. Instead the model studies the adoption of

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<sup>9</sup> The dynamic models of Ghironi and Melitz (2005) includes forward looking behavior, but it does not study anticipated future changes in trade liberalization, so like standard trade models, it does not study the possibility of trade response in the absence of a current rise in trade volume.

<sup>10</sup> Ruhl (2008) and Arkolakis (2009) allow for a distinct sunk entry cost for exporting.

a common currency as the elimination of trade costs associated with currency conversion or other reduction in the significance of national borders.

### 3.1 Goods market structure

Overall demand ( $D$ ) in the home country is an aggregate of  $n_H$  varieties of home goods and  $n_F$  varieties of goods exported from the foreign country. The aggregator is CES, with a potentially distinct elasticity between home and foreign goods aggregates ( $\phi$ ), and among varieties from a given country ( $\mu$ ).

$$D_t = \left( \theta^{\frac{1}{\phi}} (D_{H_t})^{\frac{\phi-1}{\phi}} + (1-\theta)^{\frac{1}{\phi}} (D_{F_t})^{\frac{\phi-1}{\phi}} \right)^{\frac{\phi}{\phi-1}} \quad (5)$$

where

$$D_{H_t} \equiv n_{H_t}^{\gamma - \frac{\mu}{\mu-1}} \left( \int_0^{n_{H_t}} (d_{H_t}(i))^{\frac{\mu-1}{\mu}} di \right)^{\frac{\mu}{\mu-1}} = n_{H_t}^{\gamma} d_{H_t}(i) \quad (6)$$

and

$$D_{F_t} \equiv n_{F_t}^{\gamma - \frac{\mu}{\mu-1}} \left( \int_0^{n_{F_t}} (d_{F_t}(j))^{\frac{\mu-1}{\mu}} dj \right)^{\frac{\mu}{\mu-1}} = n_{F_t}^{\gamma} d_{F_t}(j) \quad (7)$$

for homogeneous firms. Following Benassy (1996), the parameter  $\gamma$  indicates the degree of love for variety, in that  $\gamma-1$  represents the marginal utility gain from spreading a given amount of consumption on a basket that includes one additional good variety in a symmetric equilibrium.

The corresponding price indexes are:

$$P_t = \left( \theta (P_{H_t})^{1-\phi} + (1-\theta) (P_{F_t})^{1-\phi} \right)^{\frac{1}{1-\phi}} \quad (8)$$

where

$$P_{H_t} = n_{H_t}^{-\left(\gamma - \frac{\mu}{1-\mu}\right)} \left( \int_0^{n_{H_t}} (p_{H_t}(i))^{1-\mu} di \right)^{\frac{1}{1-\mu}} = n_{H_t}^{1-\gamma} p_{H_t}(i) \quad (9)$$

$$P_{F_t} = n_{F_t}^{-\left(\frac{\gamma-\mu}{1-\mu}\right)} \left( \int_0^{n_{F_t}} (p_{F_t}(i))^{1-\mu} di \right)^{\frac{1}{1-\mu}} = n_{F_t}^{1-\gamma} p_{F_t}(i) \quad (10)$$

for homogeneous firms, where  $P$  is the aggregate domestic country price level,  $P_H$  is the price index of the home good,  $P_F$  is the price (to domestic residents) of the imported foreign good.

These imply relative demand functions for domestic residents:

$$D_{H_t} / D_t = \frac{1}{2} (P_{H_t} / P_t)^{-\phi} \quad (11)$$

$$D_{F_t} / D_t = \frac{1}{2} (P_{F_t} / P_t)^{-\phi} \quad (12)$$

and

$$d_{H_t}(i) / D_{H_t} = (p_{H_t}(i) / P_{H_t})^{-\mu} n_{H_t}^{\mu(\gamma-1)-\gamma} = n_{H_t}^{-\gamma} \quad (13)$$

$$d_{F_t}(i) / D_{F_t} = (p_{F_t}(i) / P_{F_t})^{-\mu} n_{F_t}^{\mu(\gamma-1)-\gamma} = n_{F_t}^{-\gamma}. \quad (14)$$

Analogous conditions apply to the foreign country. Note that under symmetry

$$n_{H_t} = n_{F_t}^* \text{ and } n_{H_t}^* = n_{F_t}.$$

### 3.2 Home household problem

The representative home household derives utility from consumption ( $C$ ) and disutility from labor ( $L$ ). Households derive income by selling their labor ( $L$ ) at the nominal wage rate ( $W$ ), receiving real profits from home firms ( $\Pi$ ). There is no international asset trade, so trade is balanced between the two countries.

Household optimization for the home country may be written:

$$\max E_0 \sum_{t=0}^{\infty} \beta^t U(C_t, L_t)$$

subject to the budget constraint:

$$P_t C_t = W_t L_t + \Pi_t$$

where

$$U_t = \frac{C_t^{1-\rho}}{1-\rho} - \frac{L_t^{1+\psi}}{1+\psi} .$$

Optimization implies a labor supply condition:

$$\frac{W_t}{P_t C_t^\rho} = L_t^\psi , \quad (15)$$

An analogous problem and first order conditions apply to the foreign household.

### 3.3 Home firm problem

There are two types of home firms, those selling in the domestic market and those that engage in export. The markets are monopolistically competitive, with free entry subject to a one-time sunk cost,  $K_{Ht}$  for domestic firms and  $K_{Ht}^*$  for exporters. This setup cost may be viewed as a type of investment analogous to that in physical capital in other DSGE models. Home exports to the foreign market are subject to a fixed export cost each period  $F_{Ht}^*$ , in units of labor, as well as a proportional iceberg trade cost,  $\tau_{Ht}^*$ . It is assumed that fraction  $\delta$  of firms must exogenously exit the market each period. Production for all firms is linear in labor:

$$y_t(i) = A L_t(i) . \quad (16)$$

where  $A$  represents technology common to all production firms in the country.

To determine prices and entry in the home market, the home firm maximizes current home market profits plus discounted future home market profits,  $\pi_{H,t}(i) + v_{H,t}$ , where:

$$v_{H,t}(i) = E_t \left\{ \sum_{s=1}^{\infty} \left( \beta(1-\delta)^s \right) \frac{u_{c,t+s}}{u_{c,t}} \pi_{H,t+s}(i) \right\} ,$$

which is represented in the model by specifying



$$v_{H,t}(i) = E_t \left\{ \left( \beta(1-\delta) \right) \frac{u_{c,t+1}}{u_{c,t}} \left( v_{H,t+1}(i) + \pi_{H,t+1}(i) \right) \right\} \quad (17)$$

and

$$\pi_{H,t}(i) = \left[ \left( p_{H,t}(i) - \frac{W_t}{A} \right) d_{H,t}(i) \right] / P_t. \quad (18)$$

Future profits are discounted by the stochastic discount factor of domestic households,  $\beta \frac{u_{c,t+1}}{u_{c,t}}$ ,

which are assumed to own the firms. This problem implies price setting behavior as a markup over marginal cost:

$$p_{H,t}(i) = \frac{\mu}{\mu-1} \frac{W_t}{A}. \quad (19)$$

New firms deciding to enter the market in period  $t$  begin to produce goods in  $t+1$ . The entry condition is:

$$v_{H,t} = K_{H,t} \frac{W_t}{P_t A}. \quad (20)$$

Use the fact that all firms are identical to write  $v_{H,t} = v_{H,t}(i)$  and  $\pi_{H,t} = \pi_{H,t}(i)$ . New entrants augment the existing stock of firms in the market:

$$n_{H,t} = n_{H,t-1} + n e_{H,t-1} \quad (21)$$

Conditions for home firms exported abroad are analogous to those above for firms selling at home. Firm value:

$$v_{H,t}^*(i) = E_t \left\{ \sum_{s=1}^{\infty} \left( \beta(1-\delta) \right)^s \frac{u_{c,t+s}}{u_{c,t}} \pi_{H,t+s}^*(i) \right\}, \quad (22)$$

which is represented in the model by specifying

$$v_{H,t}^*(i) = E_t \left\{ (\beta(1-\delta)) \frac{u_{c,t+1}}{u_{c,t}} (v_{H,t+1}^*(i) + \pi_{H,t+1}^*(i)) \right\} \quad (23)$$

where

$$\pi_{H,t}^*(i) = \left[ \left( p_{H,t}^*(i) - \frac{W_t}{A(1-\tau_{H,t}^*)} \right) d_{H,t}^*(i) - W_t F_{H,t}^* \right] / P_t. \quad (24)$$

Optimality conditions for price setting and entry corresponding to those of the domestic firm

are as follows:

$$p_{H,t}^*(i) = \frac{\mu}{\mu-1} \frac{W_t}{A(1-\tau_{H,t}^*)} \quad (25)$$

$$v_{H,t}^* = K_{H,t}^* \frac{W_t}{P_t A}, \quad (26)$$

with new entry defined as:

$$n_{H,t}^* = n_{H,t-1}^* + ne_{H,t-1}^*. \quad (27)$$

### 3.4 Market clearing and equilibrium

Market clearing for the home goods market requires:

$$n_{H,t} d_{H,t}(i) + n_{H,t}^* \frac{d_{H,t}^*(i)}{1-\tau_{H,t}^*} = Y_t, \quad (28)$$

And labor market clearing:

$$AL_t = Y_t + n_{H,t}^* F_{H,t}^* + ne_{H,t} K_{H,t} + ne_{H,t}^* K_{H,t}^*. \quad (29)$$

Total composition of home demand:

$$D_t = C_t. \quad (30)$$

Balanced trade means:

$$P_{H,t}^* D_{H,t}^* = P_{F,t} D_{F,t}. \quad (31)$$

Shocks to iceberg trade costs will be log-normally distributed:

$$\begin{aligned} \left( \log \tau_{Ht}^* - \log \overline{\tau_H^*} \right) &= \rho_\tau \left( \log \tau_{H,t-1}^* - \log \overline{\tau_H^*} \right) + \varepsilon_{\tau,t-7}^* \\ \left( \log \tau_{Ft} - \log \overline{\tau_F} \right) &= \rho_\tau \left( \log \tau_{F,t-1} - \log \overline{\tau_F} \right) + \varepsilon_{\tau,t-7} \end{aligned} \quad (32)$$

$$\left[ \varepsilon_{\tau,t}, \varepsilon_{\tau,t}^* \right] \sim N(0, \Sigma).$$

Equilibrium is a sequence of the following 44 variables:  $C, D, P, d_H(i), d_F(i), p_H(i), p_F(i), P_H, P_F, D_H, D_F, W, L, Y, v_H, v_H^*, n_H, n_H^*, ne_H, ne_H^*, \pi_H, \pi_H^*$ , and foreign counterparts for each of these. The 44 equilibrium conditions are: price indexes and demands for types of goods (8)-(14), labor supply (15), profit and firm value (17-18, 23-24), price setting (19,25), entry and new firms (20-21, 26-27), market clearing for goods and labor markets (28, 29), definition of overall demand (30), and the foreign counterparts for all of these, along with balanced trade (31), and choice of the home consumption bundle as numeraire:

$$P = 1. \quad (33)$$

The model is solved as a linear approximation in all experiments except the final one.

### 3.5 Calibration

The macro parameters are taken at standard real business cycle values:  $\rho = 1$  (log utility),  $\psi = 1$  (unitary labor supply elasticity),  $\mu = 6$  (implying a price markup of 20%), and  $\beta = 0.96$  to represent an annual frequency. The elasticity of substitution between home and foreign goods is calibrated at  $\phi = 3$ , the median estimate from Broda and Weinstein (2006). The calibration of  $\delta = 0.10$  follows Ghironi and Melitz (2005) to match data on the annual job destruction rate of

10%. Home bias in preferences is set at  $\theta=0.66$  so that the trade share in GDP is 70%, which is representative for EU countries (European Commission, 2006).

Trade costs are calibrated based on outside studies. The steady state iceberg cost  $\overline{\tau_H^*}$  is set to 0.20, as used in Obstfeld and Rogoff (2000). The sunk costs are normalized at  $\overline{K_H} = \overline{K_H^*} = 1$ , with the fixed costs set at  $\overline{F_H^*} = 0.07$  so that 21 % of total home firms export (as in Ghironi and Melitz, 2005). For the purpose of impulse responses, we begin by assuming that trade cost shocks are permanent:  $\rho_\tau = \rho_\tau^* = 1$ .

## 4. Simulation Results

### 4.1. Benchmark model

Figure 2 reports impulse responses in log deviations from steady state. The shock is a drop in iceberg trade costs announced in period 1 that will occur in period 8, which we will refer to as period  $T$ . The timing represents the signing of the Maastricht treaty in 1992, formalizing plans to begin a common currency seven years later in 1999. The size of the shock is calibrated so that exports rise by the 12% magnitude observed in the empirical section, which requires a drop in iceberg trade costs from 0.20 to 0.165. The key result is that the figure indicates no effect on overall trade or the number of exporting firms in anticipation of the monetary union; both rise first in period  $T$  where trade costs actually fall.

This may seem surprising, since one might think that firms would be willing to pay the one-time sunk cost of entry as soon as they begin to expect a rise in profits in future periods.

But intuition comes from examining the entry condition combining (23) and (26)

$$v_{H,t}^* = E_t \left\{ \left( \beta(1-\delta) \right) \frac{u_{c,t+1}}{u_{c,t}} \left( v_{H,t+1}^* + \pi_{H,t+1}^* \right) \right\} = \frac{K_{H,t}}{A_t} \frac{W_t}{P_t}. \quad (34)$$

The general principle is that under free entry, an expectation of future trade cost reduction does not predict a rise in discounted future profits per firm, but instead a rise in the future number of firms. Begin by considering firm decisions in period  $t=T-1$  for entry in period  $t+1=T$ : firms will progressively enter this period until discounted profits per firm are driven down to the point that they just barely cover the sunk cost of entry with no extra profits left over. Because the sunk entry cost in  $T-1$  is the same as in all previous periods, entry guarantees that the value of discounted profits per firm must also be the same as in previous periods. Now consider the firm decision one period earlier, in period  $t=T-2$  for entry in  $T-1$ . Firms anticipate the equilibrium in the next period, and realize there will be no extra profits per firm, so there is no additional benefit to entry. Conversely, extra entry in period  $T-1$  would lower single-period profits in that period because monetary union has not begun and sales have not yet risen. New entry in period  $T-1$  would imply a fall in profits per firm in that initial period, so entry in  $T-1$  implies a stream of profits that will not cover the sunk cost of entry. The fact that firms correctly anticipate future entry that eats up extra future profits that might have compensated for lower profits in the initial periods before monetary union removes the incentive to enter in any earlier period.

Figure 2 coincides with this description. While single-period export firm profits do rise prior to period  $T$ , equation (34) makes clear that profits must be discounted by the marginal utility of consumption. The figure shows that consumption rises along with single-period profits to maintain a nearly constant level of discounted profit stream and firm value. Firm value rises only in period  $T$  by a small amount, along with the small rise in home wage which raises the effective entry cost when converted from labor units.

#### **4.2. Productivity heterogeneity**

One might think that firm heterogeneity could alter this result. If some firms are more productive than others, these firms will have profits even after less productive firms enter in

later periods, which would justify immediate entry of the most productive firms. We follow the convention for modeling firm heterogeneity under a sunk cost as discussed in Ghironi and Melitz (2005), hereafter GM. Firms pay the sunk cost of entry before knowing their productivity draw, so that the sunk cost decision depends upon expectations of productivity, that is, firm averages.<sup>11</sup> Our model differs from GM in that we wish to specify a sunk cost associated with the exporting decision not just firm entry into the domestic market. As in the benchmark model above, this is facilitated by assuming that exportable and domestically consumed goods are produced by distinct sectors populated by two distinct sets of firms, so that firm creation in the export sector is synonymous with entry into the export market.

For firms in the export sector, a firm-specific productivity term  $z$  augments production:

$y_t(i) = A_t z(i) L_t(i)$ . Following GM, firm productivity is assumed to follow a Pareto

distribution with shape parameter  $k$  and lower bound  $z_{\min}$ :  $G(z) = 1 - (z_{\min}/z)^k$ . Productivity

averages can be computed:  $\tilde{z} = \left[ \int_{z_{\min}}^{\infty} z^{\mu-1} dG(z) \right]^{\frac{1}{\mu-1}} = z_{\min} \left\{ k / [k - (\mu - 1)] \right\}^{1/(\mu-1)}$ . Aggregates in

the export sector can be computed as functions of this average productivity, as if the export

sector consisted of  $n_{H,t}^*$  firms each with the average productivity computed above. Because

firms choose to pay the sunk cost of entry before drawing their productivity, the export entry

decision is specified  $\tilde{v}_{H,t}^* = K_{H,t}^* \frac{W_t}{P_t A_t}$ , where average firm value is specified<sup>12</sup>

<sup>11</sup> An alternative would be to allow firms to pay the sunk cost after knowing their productivity draw as in Ruhl (2008). This would greatly amplify the complexity of model solution, as one would need to track the productivity levels of all firms at all periods, rather than taking aggregate variables as functions of average productivity as in Ghironi and Melitz (2005). We consider the possibility of heterogeneity known at the time of entry later in the paper, where heterogeneity takes a form that does not pose this problem for model solution.

<sup>12</sup> Average profits and prices are specified

$$\tilde{\pi}_{H,t}^*(i) = \left[ \left( \tilde{p}_{H,t}^*(i) - \left( W_t / A_t \tilde{z} (1 - \tau_{H,t}^*) \right) \right) \tilde{d}_{H,t}^*(i) - W_t F_{H,t}^* \right] / P_t \text{ and } \tilde{p}_{H,t}^*(i) = \frac{\mu}{\mu - 1} \frac{W_t}{A_t \tilde{z} (1 - \tau_{H,t}^*)}.$$

$$\tilde{v}_{H,t}^*(i) = E_t \left\{ \sum_{s=1}^{\infty} \left( \beta(1-\delta)^s \right) \frac{u_{c,t+s}}{u_{c,t}} \tilde{\pi}_{H,t}^*(i) \right\}. \quad (35)$$

Calibrations follow GM, setting  $z_{\min}$  to 1 and choosing  $k$  so that the standard deviation of firm size, which equals  $1/(k - \mu + 1)$ , is 1.67 to match evidence on the firm size distribution.

Figure 3 reports the impulse response to the pre-announced reduction in iceberg trade cost considered above. As in the previous model without firm heterogeneity, the figure shows there is no rise in the number of exporting firms in periods prior to the trade cost reduction. The intuition is that firms do not know before paying the sunk cost whether they will have high or low productivity, so heterogeneity has no impact on the sunk cost decision above. Firms considering the possibility of early entry expect to have the same productivity as later entrants, so they expect that their future profits will be the same as that for later entrants. As in the previous experiment, firms expect future entry will bid down profits to the point of just covering sunk costs of those future entrants. So early entry in periods of lower or negative initial profits cannot be justified by an expectation of higher than average future profits for those early entrants.

### 4.3 Main Result: Sunk cost heterogeneity

Another form that heterogeneity could take would be in sunk trade costs. Following Ruhl (2008), suppose a distribution of sunk costs  $G(K_{Ht}^*) = (K_{Ht}^*/K_{H\max}^*)^\chi$ , where  $K_{H\max}^*$  is an upper bound on the sunk cost, and  $\chi$  characterizes heterogeneity. Denoting the full set of potential exporters as  $n_{H\max}^*$  and the set of entrants at the end of a period as  $nx_H^* = n_H^* + ne_H^*$ , we write  $nx_H^* = G(K_{Ht}^*)n_{H\max}^*$ , which implies the sunk cost of the marginal entrant rises with the fraction of potential firms engaged in the market:

$$K_{H,t}^* = \left( nx_{H,t}^* / n_{H \max}^* \right)^{\frac{1}{\chi}} K_{H \max}^* . \quad (36)$$

This requires that the entry condition be written in terms of the marginal firm,  $i = nx_{H,t+1}^*$ :

$$v_{H,t}^* \left( nx_{H,t+1}^* \right) = \frac{K_{H \max}^* \left( \frac{nx_{H,t+1}^*}{n_{H \max}^*} \right)^{\chi}}{A_t} \frac{W_t}{P_t} . \quad (37)$$

Note this entry condition is different from Ghironi and Melitz (2005) in that it applies to the marginal firm, evaluated after the value of the heterogeneous sunk cost is known, rather than being evaluated for average firm value, based on expected values of the heterogeneous term. It also is simpler than the specification of Ruhl (2008), in that there is no heterogeneity in firm marginal costs or profits, which would require a different and much more complex solution method to track the evolution of heterogeneity. The main point is that firms can be ranked at any given point in time in terms of their willingness to enter the export market, and it is the sunk cost of the marginal firm that determines the equilibrium level of profit per firm in each period. So while the profit per firm after entry in period  $T$  will just cover the sunk cost of the marginal new entrant, it will more than cover the lower sunk cost of the other entrants that period, with extra profit left over. Since firms are forward looking, these firms will correctly anticipate these excess profits, and see a motivation for entry in earlier periods. Future entrants will not eat up all extra profits, because these later firms must deal with higher sunk costs.

Aggregating over heterogeneous sunk costs, the resource constraint becomes:

$$A_t L_t = Y_t + n_{Ht}^* F_{H,t}^* + n e_{H,t} K_{H,t} + \left( K_{H \max}^* / \left( n_{H \max}^* \right)^{\chi} \right) (1/\chi + 1) \left( \left( n_{Ht}^* + n e_{Ht}^* \right)^{1/\chi + 1} - \left( n_{Ht}^* \right)^{1/\chi + 1} \right) \quad (38)$$



The parameter  $\chi$  is calibrated at 0.190, the values implied by the calibration in Ruhl (2008) for the common value of productivity among our firms ( $A=1$ ).<sup>13</sup> The maximum sunk cost in the distribution,  $K_{H \max}^*$ , is taken to be twice the value of the sunk cost assumed in earlier simulations, and the maximum number of exporters,  $n_{H \max}^*$ , is assumed to be twice the steady state number of exporters in earlier simulations.

Impulse responses reported in Figure 4 indicate significant entry investment immediately in the period where the shock is announced, leading to a larger number of firms starting in the second period. Profits fall in the initial period, as new entrants divide up the given export sales among more competitors. But entry occurs nonetheless, because the fall in current profits is compensated by higher future profits for these firms with low sunk costs. As the date of the shock approaches, yet further firms enter, as there are a smaller number of periods of lower profits before the higher single-period profits begin in period  $T$ , making the present value of entry positive for a wider subset of the distribution of firms. Note also that the response in overall exports differs from that of the number of firms, in that it does not rise significantly prior to the actual shock. This coincides nicely with the empirical evidence reported earlier that the extensive margin responded to EMU several years ahead of overall exports. The reason is that while the extensive margin is driven mainly by sunk costs and forward looking behavior, the demand for imports is driven primarily by the relative price and hence by iceberg trade costs in that period.

This experiment demonstrates that expectations about a future monetary union generate a rise in the number of varieties available for consumption. Equation (7) shows that the utility

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<sup>13</sup> Ruhl (2008) introduces sunk cost heterogeneity in order to explain the entry of small exporters, which requires a correlation of sunk cost heterogeneity with productivity heterogeneity. The purpose here is different, and introducing of Ruhl's productivity heterogeneity would not be solvable using our current methods. We borrow the specification and calibration of sunk cost heterogeneity from Ruhl for convenience. The result is robust to alternative calibrations of the parameters.

of consuming imports rises as a fixed expenditure on imports is spread over more varieties, due to the love of variety,  $\gamma$ . Given that the standard Dixit-Stiglitz preferences imply a love of variety  $\gamma = \mu/(\mu - 1)$ , under our calibration utility from consumption rises by an extra 20% for each percentage rise in varieties. Given that these welfare gains begin well before the monetary union is formed due to firm entry in anticipation, one might likewise wonder what would be the implications if firms begin to expect a future dissolution of a monetary union? Given that the model is solved in a linearized form, the impulse responses for such an experiment would be the exact inverse of those in figure 4. Firms would begin to exit as soon as expectations are formed for a future dissolution and the exit would build over time, leading to an immediate loss in welfare from consumption.

Achieving entry in anticipation of EMU is by no means dependent upon a high degree of curvature in the distribution of firms, as summarized by  $\chi$ . An alternative calibration for  $\chi$  would be to match the steady state share of firms exporting, at 21%. The preceding calibration implies a value of low sunk cost in steady state and hence a large number of exporting firms. A value of  $\chi = 0.6$  restores the steady state sunk cost and share of exporting firms to the values assumed in previous experiments. Fig. 5a shows that the entry in anticipation of EMU is somewhat smaller in the earliest periods, but grows large several periods prior to EMU implementation.

Figure 5b demonstrates that for a lower depreciation rate ( $\delta = 0.01$ ), initial firm entry in anticipation of the shock equals about two thirds of the full entry when the shock is later realized. Firms are more willing to enter if they are more likely to still be around to reap the benefits of the extra profits in the future.

The result is also sensitive to the intertemporal elasticity of households,  $1/\rho$ , because this determines the stochastic discount factor used to discount future profits,  $(C_{t+s}/C_t)^\rho$ . Recall

from discussion of Figure 1 that the ability of future profits to encourage entry is dampened by the rise in consumption and the discounting of these future profits. A lower value of  $\rho$  lowers the degree of discounting implied by rising consumption. Figure 5c shows the case where  $\rho = 0.3$ , so that the rise in future profits has greater power to encourage new entry. Recall that the entry decision for entry in period  $T$  is unique, in that new entrants benefit from the increased sales induced by the shock but do not pay sunk cost at the higher wage rate induced by the shock, so there is the possibility of some degree of overshooting in the amount of entry in the initial period of the shock above the long-run level. This overshooting was precluded in Figure 2 by the fact that future rises in consumption led to greater discounting of future profits. But the figure shows that this overshooting occurs once the discounting is dampened. This offers one potential explanation to the empirical finding that the extensive margin has its maximum effect right around the time of EMU implementation, and the extensive margin retreats somewhat thereafter.

Finally, the model is used to evaluate the effects of cuts in alternative costs. Figure 6a reports the result of a news shock cutting the sunk cost of exporting firms by 5% in period 8, announced in period 1. The model simulated includes sunk cost heterogeneity as described above (with  $\chi$  calibrated at 0.6), with  $K_{H,t}^*$  from equation (36) now interpreted as the mean of an AR(1) process for sunk costs with log normal shocks. Fig. 6a shows that entry actually falls in the periods after the announcement, as firms wait for the lower sunk costs before entering. This fall in entry is at odds with the empirical evidence, and suggests that EMU does not raise trade primarily by lowering sunk costs.

Figure 6b studies the effect of a shock lowering by 5% the fixed cost of trade  $F_{H,t}^*$  in period 8, announced in period 1. This shock does predict a rise in entry prior to the shock. But it fails to predict the sizeable rise in exports; exports rise only a third as much as the rises in

entry, as the extra trade arises solely from love for variety. Further, trade rises in periods prior to the trade cost cut, as it is driven by the love of variety and hence moves in sync with the extensive margin. These failures indicate that EMU likely does not work primarily through lower fixed costs of trade.

#### 4.4 Learning by doing

Consider finally the possibility of learning by doing, whereby firms become more efficient at producing if they engaged in production and export previously. Such learning by doing has been used in the macroeconomic literature for other purposes such as generating endogenous persistence.<sup>14</sup> In the present context, one might expect that if exporting firms become more efficient from experience, this might induce firms to enter prior to EMU implementation, so that they are prepared to take greater advantage of these trade opportunities when they arise later.

Learning by doing will be modeled here in terms of the fixed cost of production,  $F$ .<sup>15</sup> Firms that were previously producing and active in the export market have acquired experience that lowers their fixed cost in future periods. For simplicity we assume there is a one-time permanent reduction in fixed costs of a given export firm by fraction  $\zeta$  starting in the firm's second period of production.

This implies modifying firm value as follows for home exporters:

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<sup>14</sup> See for example Lahiri and Johri (2008).

<sup>15</sup> Learning by doing is typically introduced by specifying marginal costs of production as a negative function of past output levels. This version is not possible in the context of a sunk cost of entry, as it would lead to a proliferation of state variables. We would have to keep track of each generation of new entrants over all past periods, and how long they have been present in the market, in order to specify their marginal costs. This would produce a complex cross-sectional distribution of marginal costs that would be difficult to aggregate over.

$$v_{H,t}^*(i) = \left( \beta(1-\delta)^s \right) \frac{u_{c,t+s}}{u_{c,t}} \pi_{H,t}^*(i) + E_t \left\{ \sum_{s=2}^{\infty} \left( \beta(1-\delta)^s \right) \frac{u_{c,t+s}}{u_{c,t}} \pi_{H,t}^*(i) \right\}, \quad (39)$$

where profits in a firm's initial period of existence is specified as:

$$\pi_{H,t}^*(i) = \left[ \left( p_{H,t}^*(i) - \frac{W_t}{A_t(1-\tau_{H,t}^*)} \right) d_{H,t}^*(i) - W_t F_{H,t}^* \zeta \right] / P_t. \quad (40)$$

Likewise for foreign exporters. The labor market clearing condition needs to be augmented to account for the extra fixed costs, which use labor:

$$A_t L_t = Y_t + \left( n e_{H_t}^* + \zeta (n_{H_t}^* - n e_{H_t}^*) \right) F_{H,t}^* + n e_{H,t} K_{H,t} + n e_{H,t}^* K_{H,t}^* \quad (41)$$

Figure 7 reports impulse responses for the usual cut in iceberg trade costs used in earlier simulations. Again results show there is no entry prior to the period of implementation. It is true that learning by doing makes firms more willing to enter during initial periods of low profits in periods before EMU implementation. But this incentive also applies to firms that enter later in the period of implementation. Because they too are willing to enter with a lower level of initial period profits, there is greater entry in the period of implementation, which brings down the equilibrium level of profit per firm in that period. Firms contemplating entry in earlier periods anticipate this additional future entry and the resulting lower future profits. This offsets the incentive for early entry, resulting in no extra entry in early periods.

#### 4.5. Uncertainty about future monetary union

Although the Maastricht Treaty already in 1992 set a date for monetary union, the final list of countries participating did not become final until announced in 1998. Our results suggest that there was entry of new exporting firms based upon an uncertain prospect for a future monetary union. The stochastic model above can analyze entry under uncertainty about trade

costs if we alter the experiment studied above in two respects. First, the model must be solved to a second order approximation rather than a linear approximation, as linearization implies certainty equivalence. Second, rather than modeling the announcement of the future monetary union as a shock to trade costs, model it as a shift in the mean of the stochastic distribution of trade costs. In particular,

$$\begin{aligned} \left( \log \tau_{Ht}^* - \log \overline{\tau_{Ht}^*} \right) &= \varepsilon_t^* \\ \left( \log \tau_{Ft} - \log \overline{\tau_{Ft}} \right) &= \varepsilon_t^* \\ \left( \varepsilon_t^*, \varepsilon_t^* \right) &\sim N(0, \sigma I). \end{aligned}$$

The means of the distributions,  $\overline{\tau_{Ht}^*}$  and  $\overline{\tau_{Ft}}$ , take the value 0.2 for the first seven periods and then drop to 0.165 in all future periods, and this shift is fully anticipated by all agents. Shocks are independently normally distributed with zero mean and benchmark standard deviation of  $\sigma$ . Although the mean of the distribution shifts in a way fully anticipated by agents, there is still uncertainty about the realized value of trade costs in a given period, as shocks make trade costs fluctuate around the mean. The trajectory of all endogenous variables are solved for a sequence of 50 draws for the shocks, and the mean over simulations is reported. We simulate the version of the model with heterogeneity in sunk as reported in Fig. 4 previously.

For a calibration of  $\sigma = 0$ , where there is no uncertainty in the model, the mean trajectories of variables are identical to those in Fig. 4, as should be expected. The maximum rise in overall trade (in period 8) is 8.7% and the rise in the number of firms is 2.1%. As the calibration of  $\sigma$  is increased, the degree of uncertainty about future trade cost levels progressively rises. Given random fluctuations in trade costs in periods after as well as before the date set for EMU adoption, it is possible that the realization of trade costs may not be smaller in a post EMU period than a period before EMU. For example, for the calibration of  $\sigma = 0.010$  the probability that trade cost in the period after EMU implementation will be

lower than the period of the announcement is 64%.<sup>16</sup> In other words there is a 36% chance that trade costs will not fall in the period of EMU implementation. The second order solution of the model indicates that this uncertainty dampens somewhat the maximum impact of the EMU announcement, but the effect is very modest. Under  $\sigma = 0.010$  the impact on the number of exporting firms remains at 98% of its impact under no uncertainty, and the trade volume rise is unaffected.

As  $\sigma$  is progressively raised the probability of a trade cost fall after EMU progressively falls. For very large  $\sigma$  the model approaches its limit of a 50/50 chance of trade costs falling, which approximates an expectation that EMU will not take place or not be effective. Fig. 8 plots what fraction of the impact under certainty survives for various levels of uncertainty. Trade volumes appear to be unaffected by the uncertainty. The extensive margin is affected noticeably only for very high degrees of uncertainty, as the probability of lower trade costs reaches close to the limit of 50%, with very minimal impacts otherwise.

One reason that uncertainty may have small effects could be the model calibration of a lower value of  $\rho$ , the coefficient of relative risk aversion, at unity. We can consider a larger degree of risk aversion at  $\rho = 3$ , which is at the upper range of risk aversion typically considered in the DSGE models. The results for this calibration of the model are also reported in Fig. 8. Trade volume is little affected by uncertainty. The extensive margin now is affected for somewhat lower degrees of uncertainty, with the impact reduced to 96% of its maximum for a probability (of trade cost reduction) of 64%, and the impact is reduced to 84% for a probability of 57%. Again the impact is reduced near zero as the probability approaches its

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<sup>16</sup> Let  $\tau_{Ht < T}^*$  represent trade cost in a period before the date of expected EMU implementation and  $\tau_{Ht > T}^*$  represent trade cost in periods after. The difference  $\tau_{Ht > T}^* - \tau_{Ht < T}^*$  is normally distributed with mean  $\overline{\tau_{Ht > T}^* - \tau_{Ht < T}^*} = -0.035$  and standard deviation  $\sqrt{2}\sigma = \sqrt{2} * 0.1 = 0.141$ . The probability that  $\tau_{Ht > T}^* - \tau_{Ht < T}^* > 0$  is 0.691.

limit of 50%. It is remarkable that even at this heightened sensitivity to risk, the results support the conclusion that firms will respond strongly to the possibility of trade cost reduction, even if there is a good deal of uncertainty about whether that future trade cost reduction will actually take place.

## **5. Conclusion**

A currency union's ability to increase international trade is one of the most debated questions in international macroeconomics. This paper employs a DSGE model to study the dynamics of these trade effects. First, original empirical work with data from the European Monetary Union finds that the extensive margin of trade (entry of new goods) responds ahead of the intensive margin (increased trade of existing goods). The number of products being traded begins to rise several years prior to the currency union adoption, peaking near the time of adoption and attenuating somewhat thereafter. A DSGE model indicates that this dynamic response in firm entry is explainable as a rational forward-looking response to a news shock about a future monetary union which is expected to lower iceberg (ie. proportional) trade costs, and where entry in the foreign market involves a one-time sunk cost that is heterogeneous across goods. The model indicates that alternative explanations for a currency union trade effect, that it lowers the sunk cost or a fixed but repeated cost of trade, are inconsistent with the dynamics of the extensive margin evidence. This finding helps identify which types of trading frictions are reduced by adopting a currency union, and it indicates that a significant fraction of the welfare gains from a monetary union are dependent upon the expectation by traders that a monetary union will continue to exist in the future.



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Table 1: Gravity regressions with EMU Indicator, European Sample

Dependent Variable	Country Fixed Effects			Country-Pair Fixed Effects			Country-Year Fixed Effects		
	(1) EXT	(2) INT	(3) OVER	(4) EXT	(5) INT	(6) OVER	(7) EXT	(8) INT	(9) OVER
EMU	0.061*	0.051	0.112*	0.058**	0.015	0.072**	0.087**	0.024	0.111+
	(0.027)	(0.043)	(0.044)	(0.014)	(0.017)	(0.017)	(0.025)	(0.056)	(0.062)
EU	0.106**	0.012	0.119**	0.143**	0.024+	0.167**	0.068*	0.006	0.074+
	(0.026)	(0.031)	(0.037)	(0.011)	(0.014)	(0.013)	(0.031)	(0.038)	(0.045)
EU Trend	-0.008**	0.011**	0.003	-0.000	0.006**	0.006**	-0.007**	0.010**	0.002
	(0.002)	(0.003)	(0.003)	(0.001)	(0.001)	(0.001)	(0.002)	(0.003)	(0.004)

\*\* indicates significance at 1% level, \* at 5%, and + at 10%. Data cover 1973-2004, 15 EU countries.

Table 2. Gravity regressions with EMU Lag and Lead Indicators, European Sample

Dependent Variable	Country Fixed Effects			Country-Pair Fixed Effects			Country-Year Fixed Effects		
	(1) EXT	(2) INT	(3) OVER	(4) EXT	(5) INT	(6) OVER	(7) EXT	(8) INT	(9) OVER
EMU_3ahead	0.093**	-0.038	0.054	0.091**	-0.079*	0.012	0.081**	0.044	0.125*
	(0.023)	(0.042)	(0.041)	(0.026)	(0.033)	(0.032)	(0.022)	(0.051)	(0.057)
EMU_2ahead	0.093**	-0.026	0.067	0.092**	-0.066*	0.025	0.097**	0.028	0.125*
	(0.024)	(0.044)	(0.044)	(0.026)	(0.033)	(0.032)	(0.022)	(0.048)	(0.055)
EMU_1ahead	0.111**	-0.006	0.105*	0.109**	-0.053	0.056+	0.081**	0.054	0.135*
	(0.033)	(0.052)	(0.050)	(0.026)	(0.034)	(0.032)	(0.027)	(0.061)	(0.067)
EMU_0ahead	0.087*	-0.008	0.080	0.086**	-0.055	0.031	0.070*	0.027	0.097
	(0.035)	(0.052)	(0.050)	(0.026)	(0.034)	(0.032)	(0.029)	(0.059)	(0.067)
EMU_1after	0.098**	-0.012	0.086	0.097**	-0.061+	0.036	0.096**	0.029	0.125+
	(0.034)	(0.056)	(0.054)	(0.027)	(0.034)	(0.033)	(0.029)	(0.065)	(0.073)
EMU_2after	0.104**	0.009	0.114*	0.102**	-0.038	0.065*	0.120**	0.007	0.127+
	(0.034)	(0.054)	(0.053)	(0.027)	(0.034)	(0.033)	(0.029)	(0.066)	(0.073)
EMU_3after	0.106**	0.026	0.132*	0.104**	-0.021	0.083*	0.127**	0.039	0.165*
	(0.034)	(0.055)	(0.055)	(0.027)	(0.034)	(0.033)	(0.029)	(0.070)	(0.077)
EMU_4after	0.027	0.163**	0.190**	0.023	0.126**	0.148**	0.108**	0.044	0.152+
	(0.038)	(0.058)	(0.059)	(0.031)	(0.040)	(0.038)	(0.036)	(0.077)	(0.084)
EMU_5after	0.029	0.188**	0.216**	0.025	0.150**	0.175**	0.120**	0.056	0.177*
	(0.039)	(0.061)	(0.061)	(0.031)	(0.040)	(0.038)	(0.038)	(0.078)	(0.086)
EU	0.107**	0.013	0.119**	0.142**	0.024+	0.167**	0.068*	0.006	0.074
	(0.026)	(0.031)	(0.037)	(0.011)	(0.014)	(0.013)	(0.031)	(0.038)	(0.045)
EU Trend	-0.008**	0.011**	0.003	-0.001	0.006**	0.006**	-0.007**	0.010**	0.002
	(0.002)	(0.003)	(0.003)	(0.001)	(0.001)	(0.001)	(0.002)	(0.003)	(0.004)

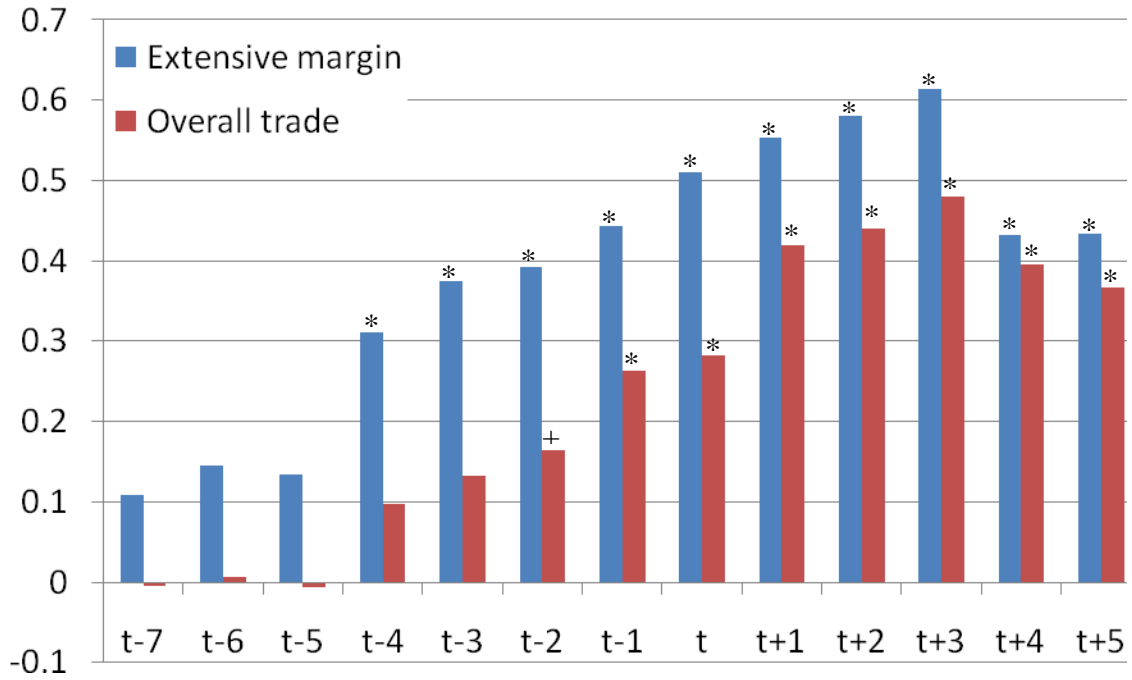
\*\* indicates significance at 1% level, \* at 5%, and + at 10%. Data cover 1973-2004, 15 EU countries.

Table 3: Gravity regressions with EMU Lag and Lead Indicators, Full Country Sample

<i>Dependent Variable</i>	<i>Country Fixed Effects</i>			<i>Country-Pair Fixed Effects</i>			<i>Country-Year Fixed Effects</i>		
	(1) EXT	(2) INT	(3) OVER	(4) EXT	(5) INT	(6) OVER	(7) EXT	(8) INT	(9) OVER
EMU_7ahead	0.230** (0.084)	-0.031 (0.052)	0.199** (0.069)	0.166** (0.088)	0.093 (0.084)	0.261** (0.090)	0.108 (0.086)	-0.113* (0.054)	-0.005 (-0.072)
EMU_6ahead	0.269** (0.087)	-0.021 (0.053)	0.248** (0.070)	0.155+ (0.088)	0.098 (0.084)	0.253** (0.090)	0.145 (0.089)	-0.138* (0.056)	0.007 (0.072)
EMU_5ahead	0.274** (0.091)	-0.021 (0.055)	0.253** (0.072)	0.112 (0.088)	0.099 (0.085)	0.211* (0.091)	0.134 (0.090)	-0.142* (0.056)	-0.007 (0.072)
EMU_4ahead	0.424** (0.088)	-0.060 (0.060)	0.364** (0.076)	0.017 (0.090)	0.082 (0.086)	0.100 (0.092)	0.311** (0.089)	-0.214** (0.061)	0.097 (0.075)
EMU_3ahead	0.492** (0.090)	-0.097 (0.061)	0.394** (0.077)	0.028 (0.090)	0.054 (0.087)	0.082 (0.093)	0.374** (0.091)	-0.240** (0.062)	0.133+ (0.076)
EMU_2ahead	0.516** (0.094)	-0.091 (0.065)	0.425** (0.079)	0.010 (0.091)	0.055 (0.087)	0.065 (0.093)	0.393** (0.094)	-0.229** (0.066)	0.165* (0.077)
EMU_1ahead	0.558** (0.097)	-0.062 (0.068)	0.496** (0.080)	-0.008 (0.091)	0.087 (0.088)	0.079 (0.094)	0.444** (0.097)	-0.181** (0.068)	0.263** (0.081)
EMU_0ahead	0.571** (0.099)	-0.082 (0.069)	0.490** (0.081)	-0.029 (0.092)	0.067 (0.088)	0.037 (0.094)	0.510** (0.100)	-0.227** (0.069)	0.283** (0.081)
EMU_1after	0.665** (0.102)	-0.108 (0.071)	0.558** (0.084)	0.011 (0.092)	0.054 (0.089)	0.064 (0.095)	0.553** (0.104)	-0.133+ (0.072)	0.420** (0.085)
EMU_2after	0.559** (0.107)	-0.036 (0.074)	0.523** (0.086)	-0.104 (0.093)	0.121 (0.089)	0.017 (0.096)	0.580** (0.105)	-0.139+ (0.073)	0.440** (0.086)
EMU_3after	0.590** (0.110)	-0.030 (0.077)	0.560** (0.091)	-0.131 (0.094)	0.132 (0.090)	0.001 (0.097)	0.613** (0.107)	-0.133+ (0.075)	0.480** (0.090)
EMU_4after	0.403** (0.121)	0.141+ (0.077)	0.544** (0.098)	-0.187+ (0.103)	0.256** (0.099)	0.069 (0.106)	0.432** (0.117)	-0.037 (0.079)	0.395** (0.099)
EMU_5after	0.409** (0.124)	0.158+ (0.080)	0.567** (0.100)	-0.255* (0.104)	0.281** (0.099)	0.026 (0.107)	0.433** (0.120)	-0.067 (0.082)	0.367** (0.102)
Custrict	1.000** (0.143)	-0.020 (0.093)	0.980** (0.170)	0.042 (0.103)	0.183+ (0.099)	0.225* (0.106)	0.974** (0.144)	-0.042 (0.091)	0.932** (0.168)
Regional	0.720** (0.109)	0.423** (0.073)	1.144** (0.115)	-0.019 (0.040)	0.213** (0.038)	0.194** (0.041)	0.648** (0.111)	0.434** (0.073)	1.082** (0.115)
EU	-0.490** (0.080)	0.253** (0.052)	-0.237** (0.084)	0.093** (0.035)	0.179** (0.034)	0.272** (0.036)	-0.525** (0.081)	0.314** (0.052)	-0.211** (0.075)
EU_Trend	-0.055** (0.005)	0.028** (0.003)	-0.027** (0.005)	-0.010** (0.002)	0.027** (0.002)	0.017** (0.002)	-0.055** (0.005)	0.025** (0.003)	-0.030** (0.005)

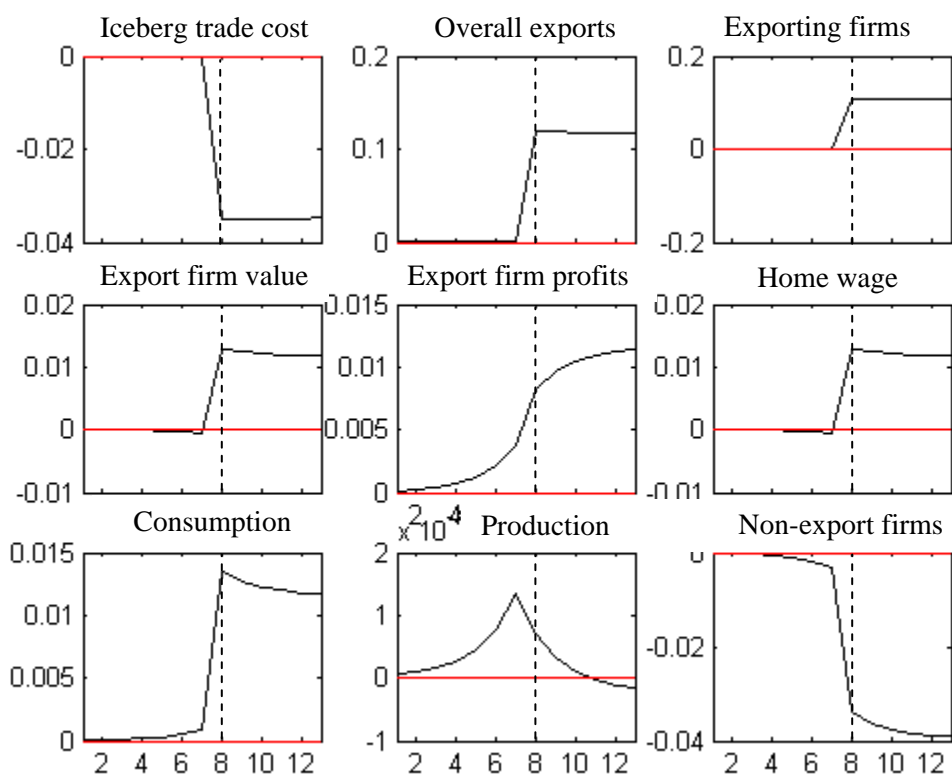
\*\* indicates significance at 1% level, \* at 5%, and + at 10%.

Fig. 1. EMU Indicators Over time  
 (Full country sample, time-varying fixed effects)



t = year of EMU adoption (1999 for most)  
 \* significant at 1%; + significant at 5%.

Fig 2: Response to an anticipated permanent symmetric fall in iceberg trade costs

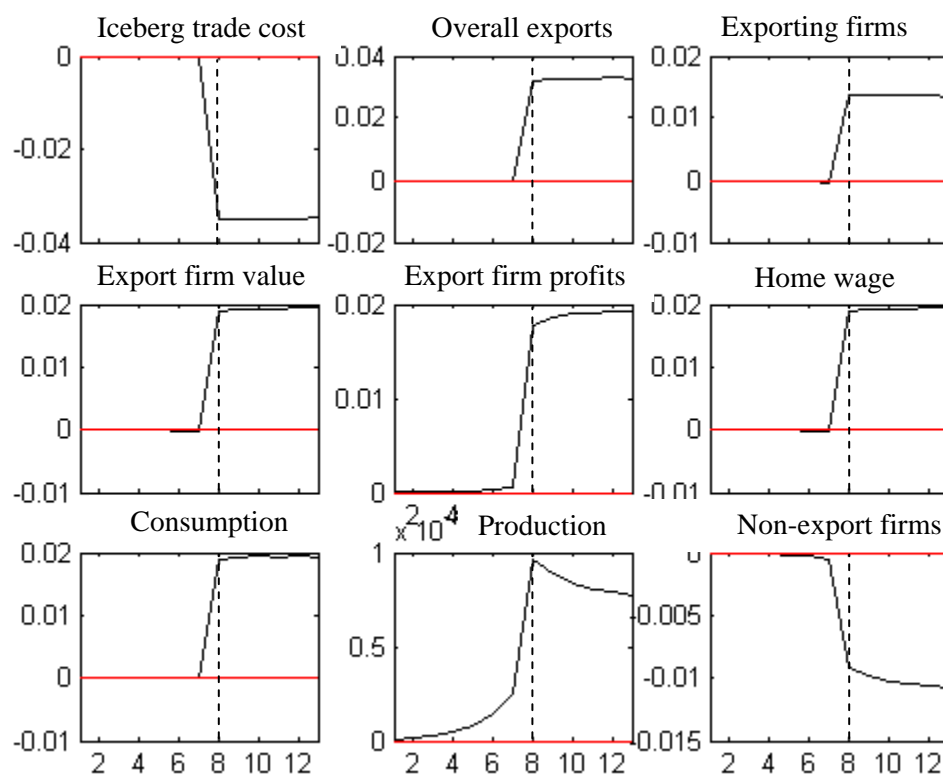


Shock: fall in iceberg cost from 0.2 to 0.165 in period 8, announced in period 1.

Benchmark calibration.

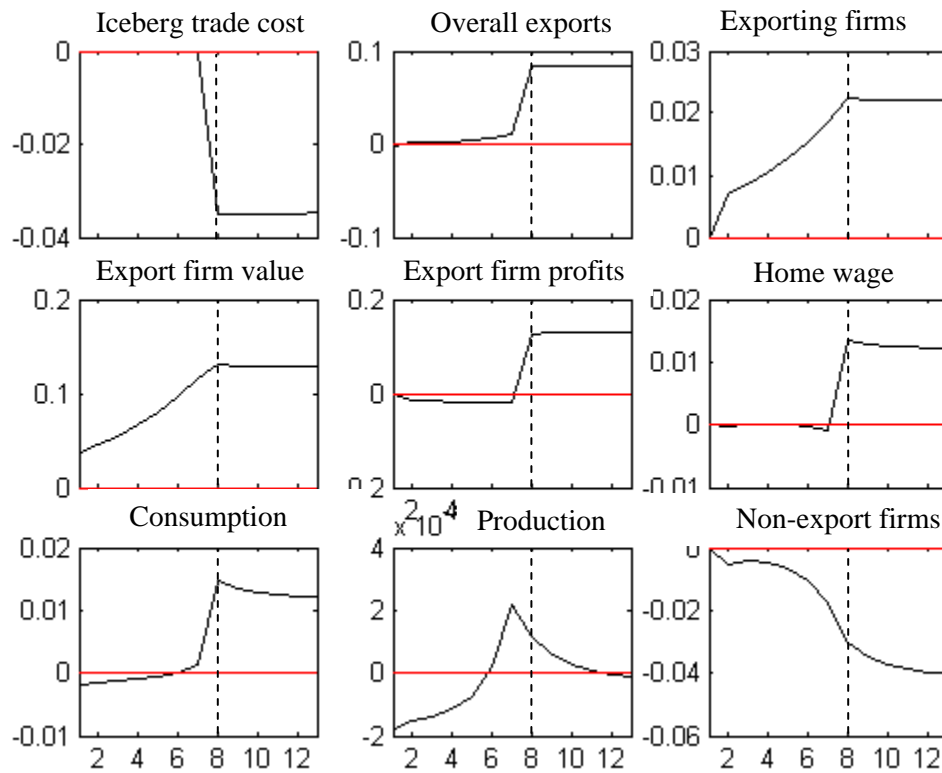
Figures report deviations from steady state in logs.

Fig 3: Productivity heterogeneity: Response to an anticipated permanent symmetric fall in iceberg trade costs



Shock: fall in iceberg cost from 0.2 to 0.165 in period 8, announced in period 1.  
 Benchmark calibration.  
 Figures report deviations from steady state in logs.

Fig 4: Response to an anticipated permanent symmetric fall in iceberg trade costs, under heterogeneity in sunk cost



Shock: fall in iceberg cost from 0.2 to 0.165 in period 8, announced in period 1.



Fig 5a: Sunk Cost Heterogeneity, Alternative Calibration ( $\chi = 0.6$ )

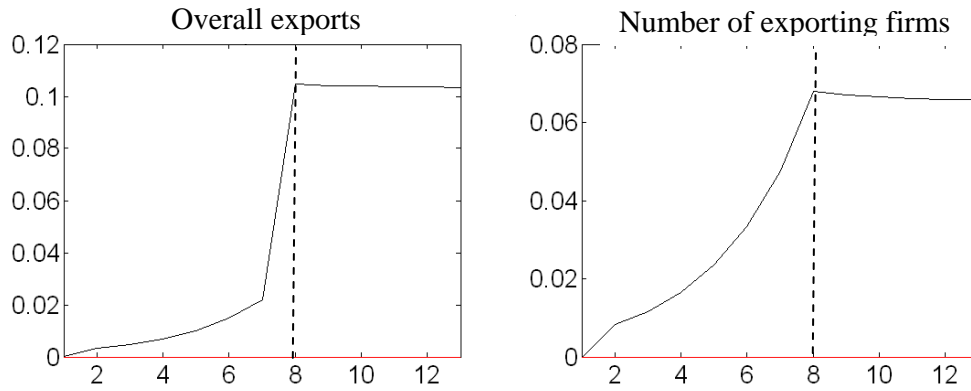


Fig 5b: Sensitivity analysis: low level of depreciation in sunk cost capital

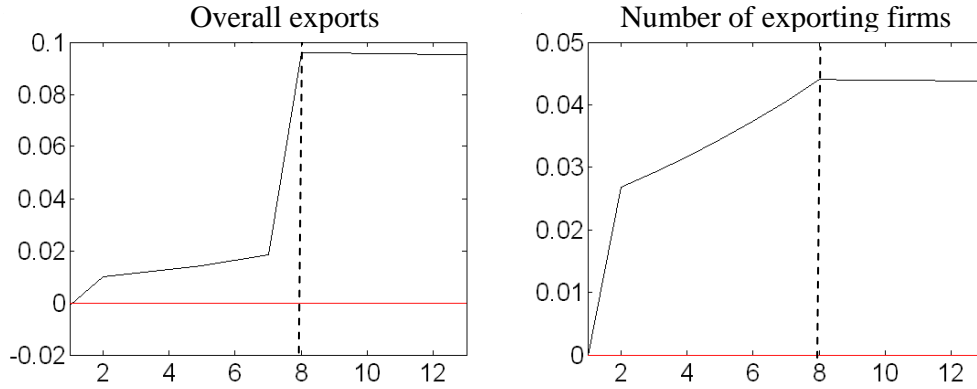
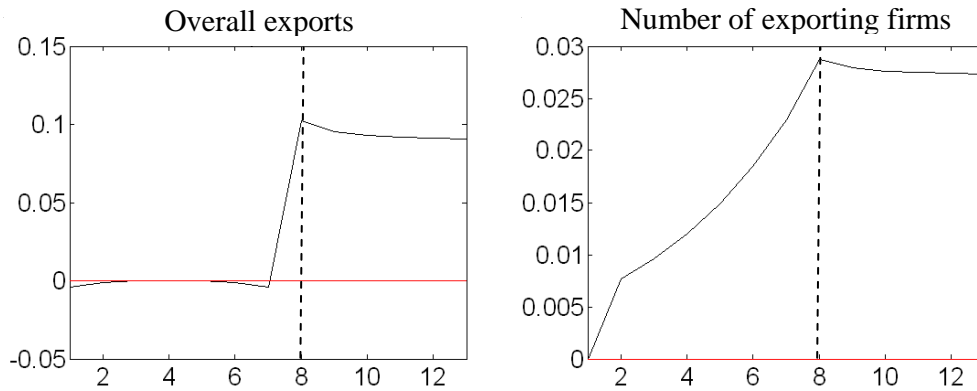
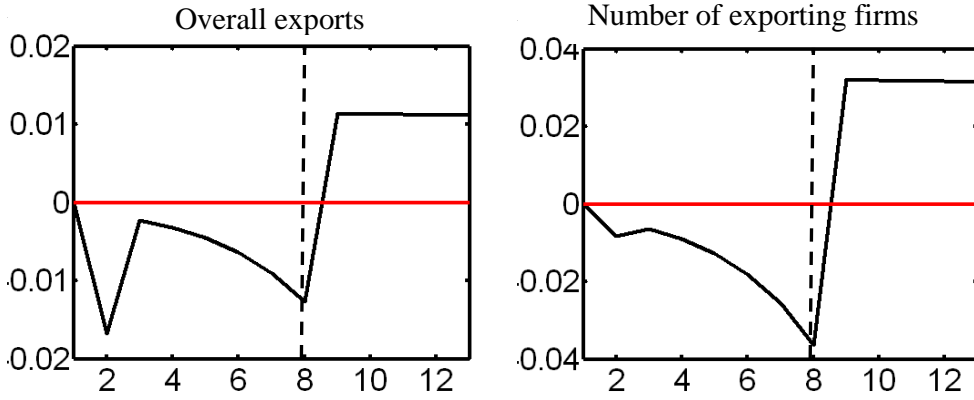


Fig 5c. Sensitivity Analysis:  $\rho = 0.3$



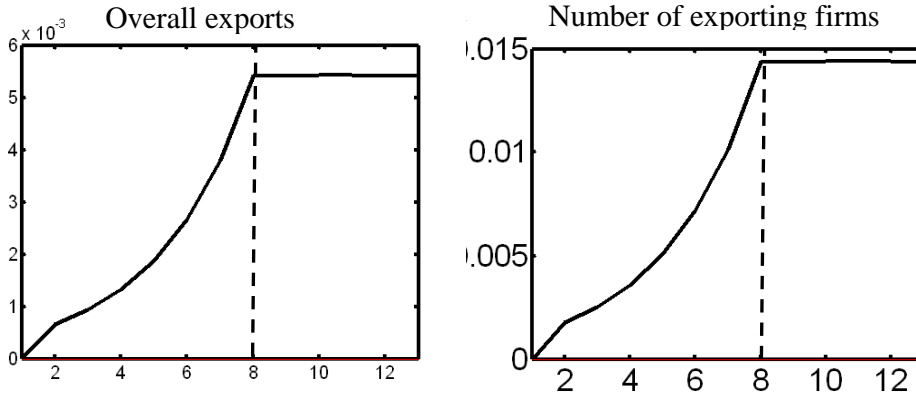
Shock: fall in iceberg cost from 0.2 to 0.165 in period 8, announced in period 1.

Fig. 6a. Response to an anticipated future permanent fall in sunk cost



Shock: fall in sunk cost by 5% in period 8, announced in period 1.

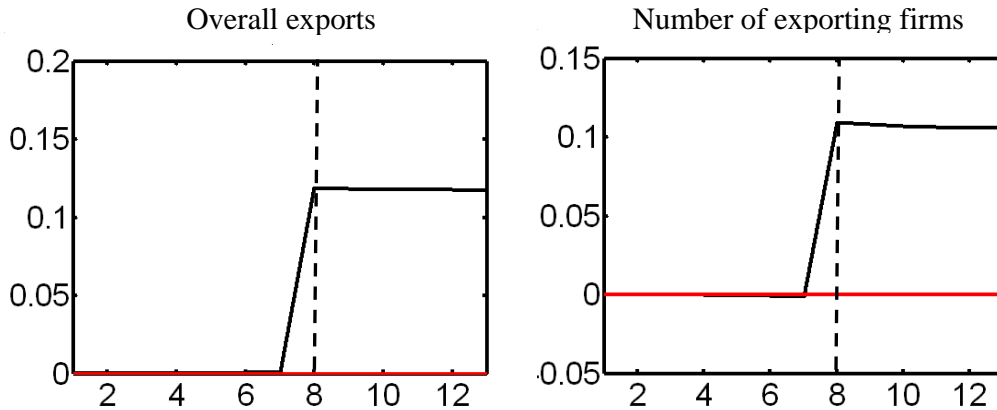
Fig 6b: Response to an anticipated future symmetric fall in fixed cost in period 8.



Shock: fall in fixed cost by 5% in period 8, announced in period 1.

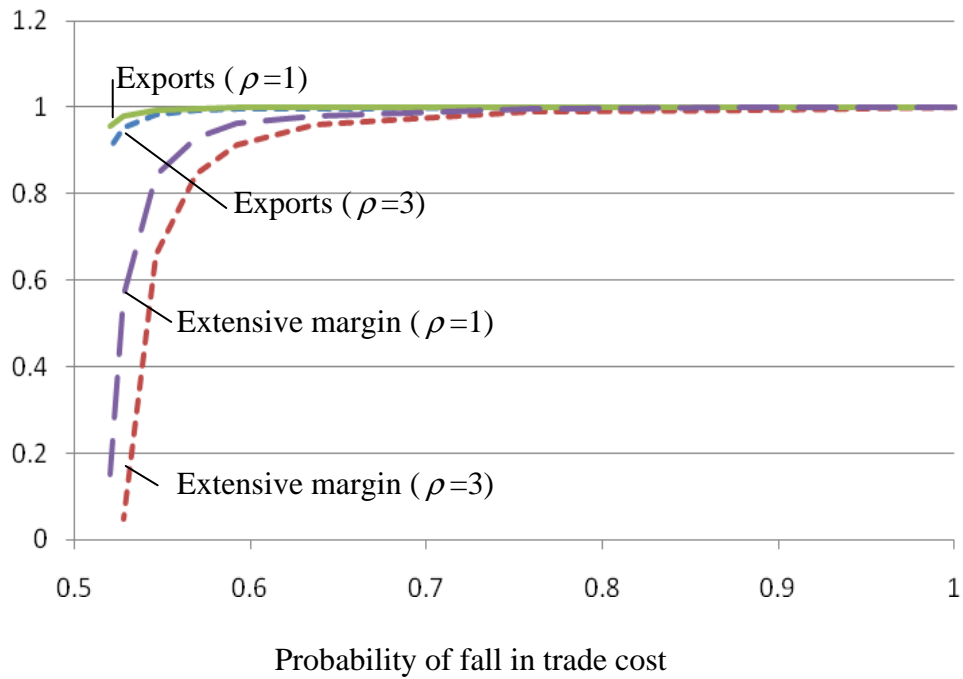
Fig 7: Learning by doing: ( $\zeta = 2/3$ )

(Response to an anticipated permanent symmetric fall in iceberg trade costs)



Shock: fall in iceberg cost from 0.2 to 0.165 in period 8, announced in period 1.

Figure 8. Effect of uncertainty



Note: The figure plots the rise in trade volume and extensive margin in period 8 as fractions of the values achieved by each under no the case of no uncertainty. The bottom axis indicates the probability that the draw of stochastic iceberg trade costs in a period after the fall in distribution mean will be lower than before the fall in distribution mean