The Dynamic Effects of a Currency Union on Trade

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Abstract

The response of trade to a monetary union is a dynamic process. An empirical study of the European monetary union finds that the extensive margin of trade in new goods responded several years ahead of EMU implementation and ahead of overall trade volume. A dynamic rational expectations trade model shows that early entry of new firms in anticipation is explainable as a rational forward-looking response to news. The model helps identify which types of trading frictions are reduced by a currency union, and shows how new entry can be affected by uncertainty about EMU.

Keywords: currency union, extensive margin of trade, trade costs

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1. Introduction

One of the benefits promised for Europe's monetary union was increased trade among member countries. A currency union's ability to increase trade has been one of the most debated questions in international macroeconomics, with recent empirical studies generally finding effects that are modest in size but statistically significant.[1] This paper studies the dynamics of these trade effects. It begins by identifying new stylized facts about the timing of effects at the various margins of trade.[2] Its theoretical contribution is to construct a dynamic rational expectations trade model that explains these dynamics as a rational forward-looking response to news. The theoretical model is used to interpret the empirical evidence and evaluate conjectures about how monetary unions lower trade costs.[3]

As motivation, the paper uses panel regressions of disaggregated trade data to study the dynamics of trade before and after the implementation of Economic and Monetary Union in Europe (EMU). Estimates indicate that the extensive margin (measured as the entry of new goods categories) responds surprisingly aggressively. There is a statistically significant rise in the extensive margin already four years ahead of actual EMU adoption, and ahead of any rise in overall trade in our main samples. The extensive margin appears to overshoot in its response, building up to a maximum shortly after the implementation of the monetary union and declining afterward, at which point the rise in overall trade volume catches up.

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

[1] Initially very large estimates were found by Rose (2000) using data from monetary unions predating EMU; support for large estimates is found in Glick and Rose (2002) and Frankel and Rose (2002). For critiques of this view see Persson (2001) and Baldwin (2006). For a sampling of empirical studies of the EMU, 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%. 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), and Baldwin et. al. (2008), estimate a rise in the extensive margin in the range of 2% to 19%. Studies using firm level data, such as Fontagné, Mayer, and Ottaviano (2009) for a subset of countries, are less supportive of an extensive margin effect, depending on how it is measured and the control group used.

[2] 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. Berger and Nitsch (2008) study the dynamics of EMU trade effects empirically by including an EMU time-trend in gravity regressions.

[3] For influential examples of models of this type, see Ghironi and Melitz (2005, 2007), Ruhl (2008), and Atkeson and Burstein (2008).

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. 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 and shifts in expectations. The model focuses on real variables and abstracts from money and nominal exchange rates. Because the countries joining EMU 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. 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 studies the effect of an announcement about a future reduction in these trade costs. The model differs from Ghironi and Melitz (2005) and most models in the literature in assuming a distinct sunk cost for exporting, which makes the entry decision forward looking and responsive to news.

The model considers a congestion externality, whereby an increase in the number of market participants raises the sunk cost of new entry. See Berentsen and Waller (2010), Vivien Lewis (2009), and Rocheteau and Wright (2005) for examples, motivated by search and advertising costs. This congestion provides an incentive for new entrants to enter early, while sunk costs remain low. This model is used to simulate the effects of news about various types of trade reforms. The main finding is that a reduction in iceberg costs of trade generate dynamics that are most consistent with the empirical facts outlined above. In contrast, news about reducing the sunk cost itself leads to an exit of firms prior to adoption rather than the early entry observed. Further, news about the fixed cost of trade fails to generate the observed rise in overall export volume upon adoption. Finally, a stochastic version of the model shows that substantial uncertainty about whether a future monetary union will actually be implemented need not preclude an entry response among firms.

This paper is closely related to portions of Burstein and Melitz (2011), which constructs a model where uncertainty about shocks implies an option value of waiting to enter. They show that news about a future trade liberalization may lead to early entry elegantly by reducing the option value of waiting. Our paper differs in the mechanism of early entry. A distinction is that our mechanism rooted in a congestion externality generates entry dynamics more similar to those observed in our particular empirical case, where early entry is large and reaches its maximum near the time of policy implementation. A mechanisms rooted in option value tends to raise entry more gradually, with much of the new entry delayed until well after trade reform occurs. In addition, Costantini and Melitz (2008) study the related issue of how firms may begin investment in technology innovation in anticipation of future trade liberalization.

The next section of the paper discusses the empirical methodology and new stylized facts. Section three defines the model, and section four discusses 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[4].

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

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

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*.

[4] 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.

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

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

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*, $EXShare_m^j$:

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

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*.

First consider some preliminary summary statistics. Trade volume as a share of GDP in our dataset increased among EMU pairs by an average of 4.9 percentage points between 1998 and 2004. Interestingly, this is nearly the same increase if one takes 1990 as the starting point, 5.5%. In contrast, the average extensive margin among EMU countries experienced much of its rise prior to EMU: the percentage rise in average extensive margin was 5.7% from 1998 to 2004, but 13.2 % starting from 1990. Further, this is much larger than the increase in the extensive margin among EU countries that did not belong to EMU, which increased only 0.8% from 1998 to 2004 and 4.2% starting from 1990. Fig. 1 plots the average extensive margin among EMU country pairs. It shows that the rise in the extensive margin over time was not even; it seemed to accelerate in the second half of the 1990s, and it had periods of decline in the post EMU period. Of course, in order to evaluate the effect of EMU separately from other factors such as EU policies and business cycles, one must control for these other factors. An effective means is by panel regressions which include controls for these factors and which include in the sample cases of countries that did not belong to EMU.

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*, 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.[5] Initial results using country fixed effects are reported in the first three columns of Table 1. Joining EMU raised overall exports

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[5] 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.

by 11.9%, which is much smaller than the effects originally found by Rose but similar to those found by other researchers focusing on a European sample.[6] 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.

To study 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.

$$Y_{jm,t} = \beta_0 + \sum_{s=-7}^{5} \beta_{1,s} EMU_{jm,t+s} + \beta_2 EU_{jm,t} + \beta_3 EUTrend_{jm,t} + \lambda X_{jm,t} + \gamma F_{jm,t} + \phi\, t + \kappa EX + \omega IM + \varepsilon_{jm,t} \quad (5)$$

Table 2 presents a first set of results on dynamics. 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.[7] The average magnitudes of this effect are similar to those found in table 1, with a time profile that grows over time, peaks shortly after EMU adoption, and falls in the final two periods.[8] The nonmonotonic time profile of the extensive margin suggests there is more than a simple time trend at work among EMU countries. The three sets of estimations vary among themselves regarding values of other coefficients, such as

[6] 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.
[7] The main results to follow will provide a more precise estimate of when extensive margin effects start. The estimations to come will be better able to identify the effects of EU membership as separate from EMU membership, as they will include countries not in the EU, against which to compare trade among EU countries. Later specifications will also contain explicit controls for time-varying effects of EU market integration.
[8] The coefficients on dynamic EMU dummies presented in Table 2 are cumulative. For example, for a country that adopted EMU in 1999, the coefficient on EMU_5after shows how much trade in 2004 is higher because of joining EMU in 1999. Because the single EMU dummy in Table 1 takes a value of 1 for all years after EMU adoption (1999 for most), while Table 2 has separate dummies for each of these years, one can compare the two tables by taking the average over the coefficients on the dummies from EMU_0ahead to EMU_5after in each column of Table 2, to find that this produces a value similar to that for the corresponding column of Table 1 on the single EMU dummy. Values will differ somewhat because the latter set of regressions also adds dummies for years prior to EMU.

whether overall trade rises prior to EMU adoption. The intensive margin is either insignificantly different from zero or negative in the run-up to EMU depending 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[9], 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 of 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.

Fig. 2 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 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.

[9] 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 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 an 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.

We conduct several checks for robustness of our results. First, countries planning to join EMU were required to participate in the ERM system of fixed exchange rates for several years prior to EMU, and it is possible that exchange rate stability might have promoted trade during those years. Table 4, columns (1-3) reports results for the regression in the full sample when controls are introduced for exchange rate volatility and the exchange rate regime. Volatility of the nominal exchange rate between countries *j* and *m* is measured as the standard deviation of the first difference of the logarithm of the monthly exchange rate between the two countries. Indicators are included for whether the countries had a direct exchange rate pegged as part of a fixed exchange rate regime such as the EMS/ERM, or whether there was an indirect peg between the pair because both pegged to the same third country.[10] Results are very similar to those in the preceding table, and all of our conclusions still hold: the extensive margin rises prior to the period of EMU implementation, it rises more than overall trade, and it tapers off after EMU implementation.

A second concern is if our measure of EU and EU trend might not capture the dynamics of EU implementation after 1992, so that part of what we pick up as effects preceding EMU might be actually lagged effects of EU integration. To investigate, we add a control consisting of an index created by the European Commission to track the progress of EU implementation and market integration after 1992. The Internal Market Index created by the European Commission is a composite of 12 indicators such as telecommunication costs and foreign direct investment flows. We use the summary of this measure created by Berger and Nitsch (2008), which sets the initial value in the base year 1992 at 20, and adds ten points for each doubling of

[10] We use the classifications of Klein and Shambaugh (2006).

the index. Fig. 3 shows the progression of EU market integration in the years after 1992. Table 4 reports regression results, which are similar to those in Table 3. EMU begins to have strongly significant effects on the extensive margin four years prior to EMU implementation, and has effects on overall trade just one year prior to implementation. Once again the extensive margin effects peak shortly after the period of implementation, and then decline. Note that like the EU indicator, the EU market integration index has a positive effect only at the intensive margin.

In additional experiments, we studied the robustness of our results to other samples. In addition to the EU sample and the full country sample, we considered three others: EU countries plus U.S., Japan and Canada, as well as a set of 18 major developed countries, and the full set of developed countries in our data set. The main results are robust across these samples, as summarized in table A1 in the online appendix. We also experimented with an empirical specification including dynamic dummies for NAFTA and EU, analogously to what we did for EMU. We tested for EU dynamic effects in 12 specifications (4 country samples, since the EU15 sample would absorb these in the year fixed effect, and 3 sets of fixed effects). Out of the 12 specifications, only 2 showed signs of positive effects of EU at the extensive margin in periods before 1992; only 3 of 12 showed any effects on overall trade. When we added NAFTA dynamic dummies to the all-country sample, we did not find statistically significant positive effects at the extensive margin for any of our 3 fixed effects specifications. Why are the dynamic effects of EMU different from EU or NAFTA? It may have something do with the fact that EMU was preceded by a massive information campaign, and practically every person in the Eurozone was aware of the currency change. It may be that broad awareness of the reform is needed in order to see large anticipation effects.

3. 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, which makes the entry decision forward looking.[11]

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

[11] Ruhl (2008), Arkolakis (2010), and Burstein and Melitz (2011) allow for a distinct sunk entry cost for exporting.

joining EMU 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 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

Final demand (*D*) in the home country is an aggregate of n_{HD} varieties of home goods and n_{FX} varieties of export goods from the foreign country. The aggregator is CES, with a potentially distinct elasticity between home and foreign goods aggregates (ϕ), and among varieties from a given country (μ).

$$D_t = \left(\theta^{\frac{1}{\phi}} \left(D_{HD,t} \right)^{\frac{\phi-1}{\phi}} + (1-\theta)^{\frac{1}{\phi}} \left(D_{FX,t} \right)^{\frac{\phi-1}{\phi}} \right)^{\frac{\phi}{\phi-1}}$$

where

$$D_{HD,t} \equiv \left(\int_0^{n_{HDt}} \left(d_{HD,t}(i) \right)^{\frac{\mu-1}{\mu}} di \right)^{\frac{\mu}{\mu-1}} = n_{HD,t}{}^{\frac{\mu}{\mu-1}} d_{HD,t} \tag{6}$$

and

$$D_{FX,t} \equiv \left(\int_0^{n_{FXt}} \left(d_{FX,t}(i) \right)^{\frac{\mu-1}{\mu}} di \right)^{\frac{\mu}{\mu-1}} = n_{FX,t}{}^{\frac{\mu}{\mu-1}} d_{FX,t} \tag{7}$$

for homogeneous firms, where $d_{HD,t}$ and $d_{FX,t}$ represent average firm demand. Likewise the demand for home exports will be:

$$D_{HX,t} \equiv \left(\int_0^{n_{HX,t}} \left(d_{HX,t}(j) \right)^{\frac{\mu-1}{\mu}} di \right)^{\frac{\mu}{\mu-1}} = n_{HX,t}{}^{\frac{\mu}{\mu-1}} d_{HX,t} \tag{8}$$

The corresponding price indexes are:

$$P_t = \left(\theta \left(P_{HD,t} \right)^{1-\phi} + (1-\theta) \left(P_{FX,t} \right)^{1-\phi} \right)^{\frac{1}{1-\phi}} \tag{9}$$

where

$$P_{HD,t} = \left(\int_0^{n_{HD,t}} \left(p_{HD,t}(i) \right)^{1-\mu} di \right)^{\frac{1}{1-\mu}} = n_{HD,t}{}^{\frac{1}{1-\mu}} p_{HD,t} \tag{10}$$

$$P_{FXt} = \left(\int_0^{n_{FXt}} \left(p_{FXt}(i) \right)^{1-\mu} di \right)^{\frac{1}{1-\mu}} = n_{FX,t}{}^{\frac{1}{1-\mu}} p_{FX,t} \tag{11}$$

for homogeneous firms, where P is the aggregate domestic country price level, P_{HD} is the price index of the home good, P_{FX} is the price (to domestic residents) of the imported foreign good, and p_{HD} and p_{FX} are average firm prices. These imply relative demand functions for domestic residents:

$$D_{HD,t} / D_t = \theta\left(P_{HD,t} / P_t\right)^{-\phi} \tag{12}$$

$$D_{FX,t} / D_t = \left(1-\theta\right)\left(P_{FX,t} / P_t\right)^{-\phi} \tag{13}$$

and

$$d_{HD,t}(i) / D_{HD,t} = \left(p_{HD,t}\left(i\right) / P_{HD,t}\right)^{-\mu} \tag{14}$$

$$d_{FX,t}(i) / D_{FX,t} = \left(p_{FX,t}\left(i\right) / P_{FX,t}\right)^{-\mu} \tag{15}$$

Analogous conditions apply to the foreign country.

3.2 Home household problem

The representative home household derives utility from consumption (*D*) 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 (Π).There is no international asset trade, so trade is balanced between the two countries.

Household optimization for the home country may be written:

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

subject to the budget constraint:

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

where

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

and Π represents the sum of profits of home firms defined below.

Optimization implies a labor supply condition:

$$\frac{W_t}{P_t D_t^{\rho}} = L_t^{\psi} \tag{16}$$

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

3.3 Home firm problem and export entry condition

We follow Ruhl (2008) and Chaney (2008) in specifying a fixed measure of domestic firms, and focusing on the decision of these firms to enter the export market. For simplicity we normalize the mass of domestic firms ($n_{HD,t} \equiv 1$), where each firm is indexed by *i* on the unit interval. Firms are assigned a ranking equal to their index, which determines the order in which they are presented the choice of whether to enter the export market.[12] Let $n_{HX,t} \in [0,1]$ denote the mass of firms that engage in exporting, where $n_{HX,t}$ also indicates the index of the marginal exporter. There is free entry into the export market with a one period lag subject to a one-time sunk cost, K_{Ht}, in labor units. Exports are subject to a fixed export cost each period F_{Ht} *t*, in units of labor, as well as a proportional iceberg trade cost, τ_{Ht}. As in Ruhl (2008), it is assumed that fraction δ of all firms must exogenously exit the export market each period, and each period a mass of new entrants are born in the domestic market as nonexporters at the end of the unit interval to maintain the constant mass of domestic firms. Define new entrants to the export market, $ne_{HX,t}$, by the flow condition:

$$n_{HX,t+1} = (1-\delta)\left(n_{HX,t} + ne_{HX,t}\right) \tag{17}$$

Production for all firms is linear in labor:

$$y_t(i) = AL_t(i). \tag{18}$$

where A represents technology common to all production firms in the country (no productivity heterogeneity among firms).

The value function of firms that enter period *t* as an exporter may be represented as the discounted sum of profits of domestic sales and export sales,

$$v_{HX,t}(i) = E_t\left\{\sum_{s=0}^{\infty}\left(\beta(1-\delta)\right)^s \frac{u_{D,t+s}}{u_{D,t}}\left(\pi_{HD,t+s}(i) + \pi_{HX,t+s}(i)\right)\right\},$$

which is represented in the model by specifying

$$v_{HX,t}(i) = \pi_{HD,t}(i) + \pi_{HX,t}(i) + E_t\left(\beta(1-\delta)\right)\frac{u_{D,t+1}}{u_{D,t}}\left(v_{HX,t+1}(i)\right). \tag{19}$$

Profits from domestic and export sales are specified, respectively

[12] The ranking of firms for entry could be endogenized with an arbitrarily small degree of heterogeneity in the sunk costs, imposing a distribution where higher indexed firms have sunk costs that are progressively higher by an arbitrarily small amount.

$$\pi_{HD,t}(i)=\left(p_{HD,t}(i)-\frac{W_t}{A}\right)\frac{d_{HD,t}(i)}{P_t}. \tag{20}$$

$$\pi_{HX,t}(i)=\left(p_{HX,t}(i)-\frac{W_t}{A(1-\tau_{H,t})}\right)\frac{d_{HX,t}(i)}{P_t}-\frac{W_t}{AP_t}F_{H,t}. \tag{21}$$

Future profits are discounted by the stochastic discount factor of domestic households, $\beta\frac{u_{D,t+s}}{u_{D,t}}$, which are assumed to own the firms. Maximizing this firm value implies the usual price setting behavior as a markup over marginal cost:

$$p_{HD,t}(i)=\frac{\mu}{\mu-1}\frac{W_t}{A} \tag{22}$$

$$p_{HX,t}(i)=\frac{\mu}{\mu-1}\frac{W_t}{A(1-\tau_{H,t})}. \tag{23}$$

A non-exporter must decide whether to remain selling only to the domestic market, or to enter the export market. Following Ruhl (2008), the non-exporter's problem is:

$$v_{HD,t}(i)=\max\left\{\begin{array}{c}\pi_{HD,t}(i)+E_t\left(\beta(1-\delta)\right)\frac{u_{D,t+1}}{u_{D,t}}v_{HD,t+1}(i)\\ \pi_{HD,t}(i)-K_{H,t}\frac{W_t}{P_tA}+E_t\left(\beta(1-\delta)\right)\frac{u_{D,t+1}}{u_{D,t}}v_{HX,t+1}(i)\end{array}\right\}. \tag{24}$$

Provided there is positive entry in *t*, ($ne_{HX,t}>0$), there will be a marginal firm that is indifferent between entering the export market and not doing so, for whom the two expressions in curly brackets in (24) are equivalent. So the following holds for the marginal firm in *t*:

$$\pi_{HD,t}(i)+E_t\left(\beta(1-\delta)\right)\frac{u_{D,t+1}}{u_{D,t}}v_{HD,t+1}(i)=\pi_{HD,t}(i)-K_{H,t}\frac{W_t}{P_tA}+E_t\left(\beta(1-\delta)\right)\frac{u_{D,t+1}}{u_{D,t}}v_{HX,t+1}(i). \tag{25}$$

This entry condition is inconvenient to solve numerically with standard tools, since $v_{HD,t+1}(i)$ is an object that involves a max operator. Provided there is positive firm entry also in *t+1*, apply the logic of the marginal firm now to *t+1*, which indicates that firms will enter the export market until the two terms in curly brackets are equal to each other in this period also. So updating (24) one period and choosing the lower expression in curly brackets, $v_{HD,t+1}(i)$ may be written as equivalent to: $\pi_{HD,t+1}(i) - K_{H,t+1}\frac{W_{t+1}}{P_{t+1}A} + E_{t+1}\left(\beta(1-\delta)\right)\frac{u_{D,t+2}}{u_{D,t+1}}v_{HX,t+2}(i)$. Note that because firms are homogeneous, the terms in this expression apply to all firms entering *t+1* as non-exporting firms, including the marginal firm from period *t*.[13] Making this substitution in (25) and simplifying, we obtain the entry condition used for simulations:[14]

$$E_t\left(\beta(1-\delta)\right)\frac{u_{D,t+1}}{u_{D,t}}\left[\pi_{HD,t+1}(i) - K_{H,t+1}\frac{W_{t+1}}{P_{t+1}A} + \left(\beta(1-\delta)\right)\frac{u_{D,t+2}}{u_{D,t+1}}v_{HX,t+2}(i)\right]$$
$$= -K_{H,t}\frac{W_t}{P_tA} + E_t\left(\beta(1-\delta)\right)\frac{u_{D,t+1}}{u_{D,t}}v_{HX,t+1}(i) \qquad (26)$$

Note that this can be simplified further by updating (19) one period to write $v_{HX,t+2}(i)$ in terms of $v_{HX,t+1}(i)$,

$$E_t\left(\beta(1-\delta)\right)\frac{u_{D,t+1}}{u_{D,t}}\left[\pi_{HD,t+1}(i) - K_{H,t+1}\frac{W_{t+1}}{P_{t+1}A} + v_{HX,t+1}(i) - \pi_{HD,t+1}(i) - \pi_{HX,t+1}(i)\right]$$
$$= -K_{H,t}\frac{W_t}{P_tA} + E_t\left(\beta(1-\delta)\right)\frac{u_{D,t+1}}{u_{D,t}}v_{HX,t+1}(i)$$

and simplifying:

$$K_{H,t}\frac{W_t}{P_tA} = E_t\left(\beta(1-\delta)\right)\frac{u_{D,t+1}}{u_{D,t}}\left[K_{H,t+1}\frac{W_{t+1}}{P_{t+1}A} + \pi_{HX,t+1}(i)\right]. \qquad (27)$$

The intuition for this entry condition is that postponing entry one period allows the firm to pay next period's discounted sunk cost of entry instead of this period's cost, but it foregoes export profits for one period as a result. Because a marginal exporter in period *t* will eventually become an exporter in future periods beyond *t+1*, regardless of the export entry decision it makes in period *t*, export profits from those future periods are the same regardless of whether the firm enters exporting in *t* or *t+1*, and hence they have no effect on the decision of which of these two periods to enter.

[13]While the argument is perhaps simpler for the case of homogeneous firms used in our model, this derivation does not strictly depend upon homogeneous firms. Provided that there is positive entry in both *t* and *t+1*, the marginal firm that does not enter exporting in *t* knows that in the next period it will be an inframarginal firm that is certain to enter exporting in *t+1*. This would likewise permit the substitution for $v_{HD,t+1}(i)$ used above.

[14] All simulations are checked to confirm that they satisfy the condition of positive entry in each period, $ne_{HX,s} > 0$ for all s. This is an easy condition to satisfy due to the assumption of substantial exogenous firm death each period.

This condition corresponds to that in Burstein and Melitz (2011), which also studies the case of entry in anticipation of future reduction in trade costs. They show that this condition can be rewritten for periods prior to the announcement of the trade cost reduction and where the value of sunk cost is constant at $\frac{K_H W}{PA}$:

$$E_t\left(\beta(1-\delta)\right)\frac{u_{D,t+1}}{u_{D,t}}\pi_{HX,t+1}(i)=\left(1-\left(\beta(1-\delta)\right)\frac{u_{D,t+1}}{u_{D,t}}\right)\frac{K_H W}{PA}.$$

They note that this requires the static profit gains from exporting must not exceed the per-period flow value of the sunk cost. Entry condition (27) allows for the general equilibrium effects on wages and prices, as well as for time-varying sunk cost level K_{Ht}.

One can use the fact that all firms are identical in their profits to write $v_{HX,t}=v_{HX,t}(i)$ and $\pi_{HX,t}=\pi_{HX,t}(i)$ for all exporting firms, and likewise for nonexporters.

3.4. Sunk cost specification

We allow for the possibility of a congestion externality in entry, in which the sunk cost of entry rises with the number of other firms. This is similar to the use of an adjustment cost of investment by Jaimovich and Rebelo (2009), which there gave agents an incentive to respond immediately to news about future productivity. We follow a specification of Berentsen and Waller (2009), which was motivated using a matching externality found in Rocheteau and Wright (2005) and common in monetary search models.[15] Specify sunk cost as a function:

$$K_{H,t}=\overline{K_H}\left(nx_{HX,t+1}\big/\overline{n_{HX}}\right)^{\chi} \tag{28}$$

where $\overline{n_{HX}}$ is the initial steady state share of domestic firms that participate in the export market, and $\overline{K_H}$ is the initial steady state level of sunk costs, both of which will be calibrated to outside empirical estimates. Here $nx_{HX,t+1}$ describes the number of firms a new entrant will be competing with when it first begins operation. Scaling by $\overline{n_{HX}}$ implies that when the number of firms is at its initial value, the sunk cost equals its initial value. But a rise in entry activity during period t (which raises the number of firms in period t+1) will raise the sunk cost of entry, where the elasticity of sunk cost is characterized by the parameter χ.

[15] See page 23 of Berentsen and Waller (2009) for the functional form on which our specification is based, and pages 7-8 for their motivation.

One nice feature of this congestion externality, is that when the sunk cost rises with firm entry, it implies that the rise in number of firms will be smaller for a given rise in sales. Models without firm heterogeneity often have the implication that 100% of new sales is absorbed in the long-run equilibrium by the extensive margin with no contribution at the intensive margin. Depending on the rate of increase of the sunk cost, the congestion externality can limit the entry of new firms and modulate the split of new sales between the extensive and intensive margins. This feature will be used below to guide the calibration of the curvature parameter χ.

This functional specification of entry costs also closely resembles that in Lewis (2009), motivated in terms of an imperfectly elastic supply of a factor specific to product entry such as advertising.[16]

3.5 Market clearing and equilibrium

Market clearing for the home goods market requires:

$$n_{HD,t}d_{HD,t}(i)+n_{HX,t}\frac{d_{HX,t}(i)}{1-\tau_{H,t}}=Y_t, \tag{29}$$

where $Y_t \equiv \int_0^1 y(i)\,di$. Labor market clearing requires:

$$L_t=\frac{Y_t}{A}+n_{HX,t}F_{H,t}+ne_{HX,t}K_{H,t}. \tag{30}$$

Balanced trade requires:

$$P_{HX,t}D_{HX,t}=P_{FX,t}D_{FX,t}. \tag{31}$$

Equilibrium is a sequence of the following 38 variables: D, P, $d_{HD}(i)$, $d_{FX}(i)$, $p_{HD}(i)$, $p_{FX}(i)$, P_{HD}, P_{FX}, D_{HD}, D_{FX}, W, L, Y, K_H, v_{HX}, n_{HX}, ne_{HX} $\pi_{HX}(i)$, $\pi_{HD}(i)$ and foreign counterparts for each of these. The 38 equilibrium conditions are: price indexes and demands for types of goods (9)-(15), labor supply (16), definition of new entrants (17), exporting firm value (19), profits from domestic and export sales (20 and 21), price setting (22 and 23), export entry (26), sunk cost specification (28), market clearing for goods and labor markets (29 and 30), and the foreign counterparts for all of these, along with balanced trade (31), and choice of the home consumption bundle as numeraire: $P=1$.

[16] On differences is that Lewis specifies the rise in entry cost as a function of the number of new entrants, rather than the total number of active firms.

The experiments will consider a one-time reform in trade costs in a future period that is announced ahead of time. The transition dynamics from the initial equilibrium to the final equilibrium are found by solving the model as a nonlinear forward looking deterministic system using a Newton-Raphson method, as described in Laffargue (1990). This method solves simultaneously all equations for each period over the simulation horizon.

3.5 Parameter values

The macro parameters are taken at standard real business cycle values: $\rho = 1$ (log utility), ψ =1 (unitary labor supply elasticity), μ =6 (implying a price markup of 20%), and β =0.96 to represent an annual frequency. The elasticity of substation between home and foreign goods is calibrated at ϕ =2, as used in Ruhl (2008). The choice of δ =0.10 follows Ghironi and Melitz (2005) to match data on the annual job destruction rate of 10%. In the presence of trade costs, a preference setting of θ =0.6 implies the trade share in GDP is 27%, which is representative for EU counties (European Commission, 2006).

Trade cost parameter values are based on outside studies. The steady state iceberg cost $\overline{\tau_H}$ is set to 0.16, as used in Obstfeld and Rogoff (2000). Fixed costs are chosen so that export firms represent 21% of all firms, $\overline{n_{HX}}$ =0.21 (from Ghironi and Melitz, 2005), requiring $\overline{F_H}$ = 0.20. The mean sunk cost parameter is set at $\overline{K_H}$ =0.189, so that sunk costs represent 12.6% of export firm sales as found in Alessandria and Choi (2007).

Existing literature is not very informative about how to calibrate the sunk cost congestion curvature parameter, χ . As noted above, one implication of this congestion externality is that fewer firms will enter for a given rise in overall sales. With no externality, the model implies that 100% of new trade is accounted for by the extensive margin. Our empirical results in tables 2-4 report a range of results for the ratio of the extensive margin to the change in overall sales in the long run (five years after EMU). Taking the average across all these cases, the extensive margin share is 0.606. Given the calibration of $\overline{K_H}$ and $\overline{n_{HX}}$ above, simulations for the model under alternative values of χ , a calibration of χ = 4.2 is found to reproduce the stylized fact for the long run above. Given that our interest is in evaluating the model's ability to match the short-run dynamics of entry, it should be fair to use the long-run behavior of the model to guide the parameter setting. This value is higher than that assumed by Berentsen and Waller (2010), which guessed a value of 0.8 in its simulations, though not with any particular calibration rationale. Their case applied to domestic entry in a closed economy, so one might expect a different value for entry into a foreign market. Lewis (2009) assumes a value of 2, again without particular rationale. We will consider robustness of our result to all these alternative calibrations, showing that the results do not depend crucially on the particular calibration of this parameter.

One final way of calibrating χ would be to compare to the heterogeneous distribution of sunk costs in Ruhl (2008), which follows a similar functional form to (27) above. One could track the cross-sectional distribution of sunk costs implied in our model as firms progressively entry the export market and incur the prevailing sunk cost. Then compare this to the distribution of heterogeneous sunk costs calibrated by Ruhl, which he calibrated in order to match cross sectional firm distributions in trade data.[17] His calibration implies a value of χ equal to 5.26, which is very close to our preferred calibration of 4.2.

4. Numerical Examples

The primary experiment studied is a drop in iceberg trade costs announced in year 1 that will occur in year 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 0.2 to 0.1.

4.1. Analysis of Entry Condition.

To demonstrate the important role played in this model by time-varying sunk costs, we first present an experiment that shuts down this part of the model by setting $\chi = 0$. Fig. 4 shows that there is no noticeable effect on overall trade or the number of exporting firms in anticipation of the monetary union; both rise first in period 8 where trade costs actually fall.

This may seem surprising, as 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. Some partial equilibrium intuition can be gained by studying the entry condition (27), which indicates that profits in periods beyond *t+1* do not affect this entry decision; regardless of

[17] Under the assumption that sunk costs are not correlated with firm productivity, as there is not firm productivity heterogeneity in our model, our parameter χ could be viewed as equal to -1/ς in Ruhl (2008). His calibration is ς = -0.19.

whether a firm enters next period or waits an extra period, it can still earn profits in periods dated *t+2* and later in either case. This can also be seen by substituting for export profits from equations (21), (23) and (8), and solving for the number of export firms (see appendix for derivation):

$$n_{HX,t+1} = \left[\frac{E_t R_{t+1}\left((1-\theta)\mu^{-\phi} \left(\frac{1}{\mu-1} \frac{W_{t+1}}{AP_{t+1}} \right)^{1-\phi} D^*_{t+1} \right)}{K_{H,t} \frac{W_t}{AP_t} - E_t R_{t+1} \frac{W_{t+1}}{AP_{t+1}} \left(K_{H,t+1} - F_{H,t+1} \right)} \left(1-\tau_{H,t+1}\right)^{\phi-1} \right]^{\frac{\mu-1}{\mu-\phi}} \qquad (32)$$

where $R_{t+1} \equiv \left(\beta(1-\delta)\right) u_{D,t+1} / u_{D,t}$ is the discount factor used by firms to discount future profits and costs. The numerator in this ratio represents the overall profit from export sales among all home firms in period *t+1*. The denominator is the difference in sunk and fixed costs incurred by a firm by entering the market at the end of period *t* rather than waiting an extra period: it foregoes sunk cost in period *t+1*, but must pay sunk cost in period *t* and fixed cost in period *t+1*). So the number of firms is determined by how many firms can divide up the export profits next period, and still cover the extra entry costs a new entrant would have to pay. The exponent $\frac{\mu-1}{\mu-\phi}$ is positive under the calibration above (μ=6 and ϕ=2).

Equation (32) shows that three exogenous trade cost terms have direct effects on firm entry: iceberg trade costs affecting the first period of firm activity ($\tau_{H,t+1}$), fixed costs for that period ($F_{H,t+1}$), and sunk costs for both the current period and subsequent period ($K_{H,t}$ and $K_{H,t+1}$). These trade costs could potentially also have indirect effects working through the general equilibrium values of future real wage (W_{t+1}/P_{t+1}) and overall aggregate demand (D_{t+1} and D^*_{t+1}). Note that expectations for iceberg and fixed trade costs in future periods, such as $\tau_{H,t+2}$ do not directly enter this condition. This helps explain why our simulation in Fig. 4 shows no noticeable rise in firm entry in response to an anticipated future reduction in iceberg trade costs for periods earlier than period 8 when the iceberg trade reduction actually takes effect. While a future reduction in trade cost may raise export sales and profits in period *t+2*, this does not enter the condition above because a firm can get its share of these profits regardless of whether it enters the export market for *t+1* or *t+2*. As a result, the same number of firms that were non-exporters before the announced trade liberalization will continue to find it optimal to not enter exporting ahead of the reduction in trade costs. Again, it is theoretically possible that general equilibrium effects on the real wage or overall demand could alter this conclusion. However, the numerical simulation reported in Fig. 4, which takes into consideration all these general equilibrium effects, indicates that these effects are extremely small for our parameterized model.[18]

4.2 Benchmark Model

Equation (32) includes sunk costs for multiple periods ($K_{H,t}$ and $K_{H,t+1}$), which suggests that time variation in sunk costs can influence firm entry. If the value of sunk cost in *t+1* is higher than period *t*, this lowers the denominator in the expression and raises the amount of new entry already this period. This rise in the value of sunk cost could take place either because the number of labor units required for entry varies by time (*K*), or because the cost per labor unit varies over time (*W/P*). However, our simulations show that general equilibrium effects on the real wage play no perceptible role in our experiments of anticipated future trade cost reductions.[19] As a result, we now focus on the benchmark version of the model, which endogenizes the sunk cost, *K*.

Fig. 5 reports impulse responses for the benchmark model, including the time varying sunk cost specification in (28). The figure indicates significant entry investment immediately in the period where the shock is announced, leading to a larger number of firms starting already in the second period. 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 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.

[18] For example, a rise in entry activity in *t+1* in anticipation of lower iceberg costs in *t+2* could be expected to raise labor demand and hence the real wage in *t+1*. This would raise the value of sunk costs for entry in that period and induce firms to enter an earlier period in order to pay a lower value of sunk cost. Simulations show that this has essentially no effect on the results, because the rise in real wage in t+1 is nearly exactly equal to the rise in consumption, and the reciprocal of consumption is used in the discount factor to evaluate future sunk costs under log utility. The reason for this linkage can be seen most clearly from the labor supply condition (16) for the case of utility that is log in consumption and labor supply elasticity approaching 0, where $W_t / P_t = D_t$. The denominator of entry condition (32) can then be written: $K_{H,t} \frac{W_t}{AP_t} - E_t \left(\beta(1-\delta)\right) \frac{W_t}{AP_t} \left(K_{H,t+1} - F_{HX,t+1}\right)$ which is no longer affected by future real wages dated *t+1*.

[19] The explanation provided in the previous note likewise applies here.

The logic of how the congestion externality generates early entry is similar in spirit to the role of the investment adjustment cost in Jaimovich and Rebelo (2009), where the desire to smooth investment over time led to investment rising in the initial period of news. To understand the logic of early entry in the present context, suppose for a moment that it did not occur, so that the entry dynamics followed the path in Fig. 4 instead, with the number of firms rising only in period *T* when iceberg trade costs actually fall. According to the sunk cost specification in (28) a rise in $n_{XH,T}$ indicates a rise in sunk costs of firms engaging in entry activity in period *T-1*, due to the congestion externality of the larger number of firms. A rise in $K_{H,T-1}$ relative to $K_{H,T-2}$ would induce some firms to decide to enter already in period *T-2*. This can be seen in the fact that it raises the denominator of the entry condition (32). However, the entry of some firms in *T-2* would then raise the sunk cost already in *T-2*, and thereby induce some of these firms to entry in *T-3* instead. This logic can be applied recursively, leading to early entry all the way back to the initial period where the iceberg trade cost reduction is announced. The degree to which entry in one period translates into higher sunk costs and higher entry in the preceding period depends upon several factors in the model, including parameters governing the discounting of future profits, β , the probability of an entrant surviving the period of early entry, 1-δ , and the degree to which congestion raises sunk costs, χ . Fig. 6 illustrates that a rise in any of these three factors leads to more entry in earlier periods.[20]

While this congestion externality smoothes out the rise in entry prior to period *T*, it is not symmetric across time, and it does not lead to a continued smooth rise in entry after period *T*. Rather, the number of firms reaches its long-run level in period *T* and stays at that level. This feature corresponds with the empirical observation from Fig. 2 that the maximum level of entry occurs around the time of implementation. In contrast, an alternative specification of endogenous entry costs as a type of quadratic adjustment cost would imply a symmetric smoothing out of entry both before and after implementation, so that it would take many periods after *T* before full entry is achieved. This does not correspond to the empirical evidence in Fig. 2. Fig. 6 illustrates this for a case where (28) is replaced by

[20] The figures show that a reduction in the discounting of future profits induces a greater long run response in the number of firms, which thereby translates into a proportionately greater quantity of entry in preceding periods also. On the other hand, a greater curvature in the sunk cost function that implies a more rapid rise in the sunk cost dampens the long run effect on entry at the same time that it provides a greater incentive for early entry before the sunk costs rise.

$K_{H,t} = \left(nx_{HX,t+1} / nx_{HX,t} \right)^{\chi} \overline{K_H}$, specifying an adjustment cost as a function of the change in the number of firms from period *t* to *t+1* , instead of just the level in period *t+1*.

In fact, it is quite simple to replicate some degree of the overshooting of firm entry observed in Fig 2. Recall from Fig. 5 that wages and consumption rise by similar percentages after the liberalization. The fact that wages rise after liberalization means that the value of sunk costs of entry are lower prior to liberalization than they will be in the future. This should induce a greater degree of entry activity in this period, even greater than in future periods after the liberalization has taken effect, which should induce overshooting of the extensive margin relative to the long run level. However, this effect is masked by the fact that consumption rises at the same time as wage, and consumption enters the discounting of future profits in the firm's value function. The expectation of lower marginal utility of consumption in periods after the liberalization compared to the present period lowers the valuation of profits in those periods, reducing entry. This latter general equilibrium effect can be filtered out by recalibrating the curvature of utility at ρ =0.1. This case may be practically relevant in that it approximates what firm behavior would be if firms did not discount profits using household marginal utility. Fig. 7 shows that this case does generate overshooting in the extensive margin.

Next, the model is used to evaluate the effects of cuts in alternative trade costs. Fig. 8 reports the result of a cut in the average level of sunk cost of exporting ($\overline{K_H}$ and $\overline{K_F}$) by 5% in period 8, announced in period 1. Entry actually falls in the periods after the announcement, as firms in *T-1* rather wait one period, foregoing one period of profit in exchange for paying a lower sunk cost. Under the congestion externality, this effect is passed on to even earlier periods, as a reduction in the number of firms works to lower the entry cost of new firms. Only after period *T* when the exogenous reduction in sunk trade cost is implemented will there be a rise in the number of firms. The effect on overall trade is small: only after firm entry rises will this induce a small amount of additional trade through variety effects. In sum, the fall in entry in anticipation of trade liberalization in the simulation is at odds with the empirical evidence of positive early entry, and suggests that EMU does not raise trade primarily by lowering sunk costs.

Fig. 9 studies the effect of a shock lowering by 5% the fixed cost of trade ($F_{H,t}$ and $F_{F,t}$) 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: the rise in exports in period *T* is only a tenth the rise in the extensive margin. Further, it predicts a rise in overall trade in periods prior to the trade cost cut, rather than waiting until period *T*. Both failings result from the fact that changes in overall export level are driven by variety effects, which coincide in timing with firm entry, but are smaller in magnitude than firm entry. These failures to match the empirical findings would suggest that EMU likely does not work primarily through lower fixed costs of trade.

4.3. Uncertainty about future monetary union

Although the Maastricht Treaty already in 1992 set a date for monetary union, there was uncertainty about the final list of countries until announced in 1998. Our empirical results suggest that there was entry of new exporting firms based upon an uncertain prospect for a future monetary union. The model must be made stochastic in order to study entry under uncertainty. Assume that trade costs follow the following stochastic process:

$$\left(\log \tau_{Ht} - \log \overline{\tau_{Ht}}\right) = \varepsilon_{Ht}$$
$$\left(\log \tau_{Ft} - \log \overline{\tau_{Ft}}\right) = \varepsilon_{Ft}$$
$$\left(\varepsilon_{Ht}, \varepsilon_{Ft}\right) \sim N\left(0, \sigma I\right).$$

Shocks are independently normally distributed with zero mean and benchmark standard deviation of σ. The experiment now will be a shift in the mean of the distribution of trade costs, $\overline{\tau_{Ht}}$ and $\overline{\tau_{Ft}}$, from the value 0.2 for the first seven periods, dropping to 0.1 in all future periods, and this shift in distribution is fully anticipated by all agents. 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 stochastic model will be solved for a second order approximation. 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 benchmark version of the model with time-varying sunk cost, except that we set the fixed cost to zero ($F_H = F_F = 0$). This is to rule out the possibility that a particularly large realization of trade costs would lead to endogenous exit of firms from the export market.

For a setting of σ =0, where there is no uncertainty in the model, the mean trajectories of variables are very similar to Fig. 5, with significant anticipation effects on the extensive margin prior to period *T*, and a maximum effect occurring in period *T*=8. As the value of σ 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, firms know 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 setting of σ =0.010 the probability that trade cost in the period after EMU implementation will be lower than the period of the announcement is 64%.[21] In other words there is a 36% chance that trade costs will not fall in the period of EMU implementation. Fig. 10 plots what fraction of the impact under certainty survives for various levels of uncertainty. Specifically, it plots the maximum rise in trade (from period 1 to period *T*) in the uncertainty case for that value of σ, as a ratio to the corresponding rise in trade in the model with no uncertainty (σ = 1). The same ratio is plotted for the extensive margin for each value of sigma. The horizontal axis translates sigma into the implied probability of a drop in realized trade costs.

The level of exports appears in Fig. 10 to be essentially unaffected by the uncertainty, as firms make the decision of price setting and exports after trade costs are actually realized for that period, thereby eliminating uncertainty for this decision. As long as the expected value of trade costs falls in period *T*, the mean value of exports in stochastic simulations falls the same amount regardless of the uncertainty in trade costs ex ante. In contrast, the extensive margin shows larger effects in response to uncertainty. Because firms must make the entry decision prior to the realization of trade costs for the next period, uncertainty about future trade costs implies risk associated with a new export entry decision. Nonetheless, the effect of uncertainty on the extensive margin remains fairly small for moderate levels of uncertainty, and the effect becomes large only if the probability of trade costs actually falling in period *T* falls to around 60%. For example, even if the probability of a reduction in realized trade costs in period *T* is 60%, the rise in extensive margin is still 97.5% of its value under no uncertainty. But if the probability drops to 52%, the rise in extensive margin drops to 64% of its value under certainty. This suggests that as long as European firms assigned even a modest probability to EMU actually lowering trading costs, it is reasonable for the extensive margin to respond to that expectation.

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[21] 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 $\overline{\tau_{Ht>T}} - \overline{\tau_{Ht<T}}$ = -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.

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 dynamic rational expectations trade 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. Model simulations indicate 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 exhibits a congestion externality. 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.

The finding that the extensive margin response to a monetary union is forward looking implies that some of the welfare gains, which work through love of variety in utility, rely upon expectations of a monetary union and precede its actual adoption. This may also suggest that gains from EMU rely in part upon expectations for the union's credibility for the future.

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Table 1: Gravity regressions with EMU indicator, European sample

Dependent Variable	*Country Fixed Effects* (1) Extensive margin	(2) Intensive margin	(3) Overall trade	*Country-Pair Fixed Effects* (4) Extensive margin	(5) Intensive margin	(6) Overall trade	*Country-Year Fixed Effects* (7) Extensive margin	(8) Intensive margin	(9) Overall trade
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)
Observations	5824	5824	5824	5824	5824	5824	5824	5824	5824
# of country pairs FE				182	182	182			
R-Square	0.79	0.87	0.92	0.26	0.27	0.60	0.83	0.89	0.93

** indicates significance at 1% level, * at 5%, and + at 10%. Data cover 1973-2004, 15 EU countries.
The model is estimated by ordinary least squares with robust standard errors clustered in export pair level. The dependent variables 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, $EMU_{jm,t}$. Also included are dummies for European Union and trend, $EU_{jm,t}$ and $EUTrend_{jm,t}$. Also included but not shown are regressors 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*, a dummy variable indicating whether the two countries had a free trade agreement at time *t*, the logarithm of distance between country *j* and *m*, a common language dummy, a land border dummy. Also included is a time effect, *t* and two vectors of dummy variables indicating exporter and importer fixed effects.

Table 2. Gravity regressions with EMU lag and lead indicators, European sample

	Country Fixed Effects			*Country-Pair Fixed Effects*			*Country-Year Fixed Effects*		
Dependent Variable	**(1) Extensive margin**	**(2) Intensive margin**	**(3) Overall trade**	**(4) Extensive margin**	**(5) Intensive margin**	**(6) Overall trade**	**(7) Extensive margin**	**(8) Intensive margin**	**(9) Overall trade**
EMU_7ahead	0.083**	0.018	0.101*	0.082**	-0,033	0.049	0.085**	0.074	0.159**
	(0.023)	(0.037)	(0.041)	(0.026)	(0.033)	(0.032)	(0.022)	(0.053)	(0.057)
EMU_6ahead	0.116**	0.018	0.134**	0.118**	-0.032	0.086**	0.098**	0.095+	0.193**
	(0.025)	(0.038)	(0.043)	(0.026)	(0.033)	(0.032)	(0.023)	(0.054)	(0.059)
EMU_5ahead	0.130**	0.002	0.132**	0.131**	-0.055	0.076*	0.111**	0.047	0.158*
	(0.028)	(0.045)	(0.049)	(0.026)	(0.034)	(0.033)	(0.027)	(0.062)	(0.066)
EMU_4ahead	0.133**	-0.012	0.121*	0.134**	-0.069*	0.065*	0.110**	0.052	0.162*
	(0.030)	(0.051)	(0.053)	(0.026)	(0.034)	(0.033)	(0.028)	(0.067)	(0.073)
EMU_3ahead	0.130**	-0.037	0.093+	0.131**	-0.095**	0.036	0.116**	0.062	0.178*
	(0.030)	(0.053)	(0.053)	(0.027)	(0.034)	(0.033)	(0.028)	(0.070)	(0.078)
EMU_2ahead	0.131**	-0.027	0.104+	0.132**	-0.085*	0.047	0.130**	0.045	0.175*
	(0.032)	(0.056)	(0.055)	(0.027)	(0.034)	(0.033)	(0.029)	(0.067)	(0.076)
EMU_1ahead	0.134**	-0.005	0.128*	0.135**	-0.064*	0.071*	0.102**	0.066	0.168*
	(0.037)	(0.059)	(0.057)	(0.027)	(0.034)	(0.033)	(0.032)	(0.073)	(0.080)
EMU_0ahead	0.110**	-0.007	0.103+	0.112**	-0.065*	0.046	0.090**	0.039	0.128
	(0.039)	(0.059)	(0.057)	(0.027)	(0.034)	(0.033)	(0.034)	(0.071)	(0.080)
EMU_1after	0.119**	-0.0113	0.107+	0.120**	-0.070*	0.050	0.114**	0.040	0.154+
	(0.038)	(0.062)	(0.059)	(0.027)	(0.034)	(0.033)	(0.034)	(0.075)	(0.085)
EMU_2after	0.125**	0.010	0.135*	0.126**	-0.047	0.079*	0.137**	0.018	0.155+
	(0.038)	(0.060)	(0.059)	(0.027)	(0.034)	(0.033)	(0.033)	(0.076)	(0.084)
EMU_3after	0.127**	0.027	0.154*	0.128**	-0.030	0.097*	0.143**	0.049	0.193*
	(0.037)	(0.061)	(0.060)	(0.027)	(0.034)	(0.033)	(0.033)	(0.080)	(0.088)
EMU_4after	0.047	0.164**	0.212**	0.046	0.116**	0.163**	0.125**	0.054	0.178+
	(0.041)	(0.062)	(0.063)	(0.031)	(0.040)	(0.038)	(0.040)	(0.086)	(0.095)
EMU_5after	0.049	0.189**	0.238**	0.048	0.141**	0.189**	0.136**	0.066	0.201*
	(0.041)	(0.064)	(0.065)	(0.031)	(0.040)	(0.038)	(0.042)	(0.087)	(0.096)
EU	0.106**	0.012	0.118**	0.140**	0.023+	0.163**	0.068*	0.005	0.073
	(0.026)	(0.031)	(0.038)	(0.011)	(0.014)	(0.013)	(0.033)	(0.040)	(0.047)
EU_Trend	-0.008**	0.011**	0.003	-0.001	0.006**	0.005**	-0.007**	0.010**	0.002
	(0.002)	(0.003)	(0.003)	(0.001)	(0.001)	(0.001)	(0.002)	(0.003)	(0.004)
Observations	5824	5824	5824	5824	5824	5824	5824	5824	5824
# of country pair FE				182	182	182			
R-Squared	0.79	0.87	0.92	0.26	0.27	0.60	0.83j	0.89	0.93

** indicates significance at 1% level, * at 5%, and + at 10%. Data cover 1973-2004, 15 EU countries.
The model is estimated by ordinary least squares with robust standard errors clustered in export pair level. The dependent variables 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, $EMU_{jm,t}$.over various leads and lags. Also included are dummies for European Union and trend, $EU_{jm,t}$ and $EUTrend_{jm,t}$. Also included but not shown are regressors 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*, a dummy variable indicating whether the two countries had a free trade agreement at time *t*, the logarithm of distance between country *j* and *m*, a common language dummy, a land border dummy. Also included is a time effect, *t* and two vectors of dummy variables indicating exporter and importer fixed effects.

Table 3: Gravity regressions with EMU lag and lead indicators, full sample

Dependent Variable	*Country Fixed Effects* (1) Extensive margin	(2) Intensive margin	(3) Overall trade	*Country-Pair Fixed Effects* (4) Extensive margin	(5) Intensive margin	(6) Overall trade	*Country-Year Fixed Effects* (7) Extensive margin	(8) Intensive margin	(9) Overall trade
EMU_7ahead	0.230**	-0.031	0.199**	0.166**	0.093	0.261**	0.108	-0.113*	-0.005
	(0.084)	(0.052)	(0.069)	(0.088)	(0.084)	(0.090)	(0.086)	(0.054)	-(0.072)
EMU_6ahead	0.269**	-0.021	0.248**	0.155+	0.098	0.253**	0.145	-0.138*	0.007
	(0.087)	(0.053)	(0.070)	(0.088)	(0.084)	(0.090)	(0.089)	(0.056)	(0.072)
EMU_5ahead	0.274**	-0.021	0.253**	0.112	0.099	0.211*	0.134	-0.142*	-0.007
	(0.091)	(0.055)	(0.072)	(0.088)	(0.085)	(0.091)	(0.090)	(0.056)	(0.072)
EMU_4ahead	0.424**	-0.060	0.364**	0.017	0.082	0.100	0.311**	-0.214**	0.097
	(0.088)	(0.060)	(0.076)	(0.090)	(0.086)	(0.092)	(0.089)	(0.061)	(0.075)
EMU_3ahead	0.492**	-0.097	0.394**	0.028	0.054	0.082	0.374**	-0.240**	0.133+
	(0.090)	(0.061)	(0.077)	(0.090)	(0.087)	(0.093)	(0.091)	(0.062)	(0.076)
EMU_2ahead	0.516**	-0.091	0.425**	0.010	0.055	0.065	0.393**	-0.229**	0.165*
	(0.094)	(0.065)	(0.079)	(0.091)	(0.087)	(0.093)	(0.094)	(0.066)	(0.077)
EMU_1ahead	0.558**	-0.062	0.496**	-0.008	0.087	0.079	0.444**	-0.181**	0.263**
	(0.097)	(0.068)	(0.080)	(0.091)	(0.088)	(0.094)	(0.097)	(0.068)	(0.081)
EMU_0ahead	0.571**	-0.082	0.490**	-0.029	0.067	0.037	0.510**	-0.227**	0.283**
	(0.099)	(0.069)	(0.081)	(0.092)	(0.088)	(0.094)	(0.100)	(0.069)	(0.081)
EMU_1after	0.665**	-0.108	0.558**	0.011	0.054	0.064	0.553**	-0.133+	0.420**
	(0.102)	(0.071)	(0.084)	(0.092)	(0.089)	(0.095)	(0.104)	(0.072)	(0.085)
EMU_2after	0.559**	-0.036	0.523**	-0.104	0.121	0.017	0.580**	-0.139+	0.440**
	(0.107)	(0.074)	(0.086)	(0.093)	(0.089)	(0.096)	(0.105)	(0.073)	(0.086)
EMU_3after	0.590**	-0.030	0.560**	-0.131	0.132	0.001	0.613**	-0.133+	0.480**
	(0.110)	(0.077)	(0.091)	(0.094)	(0.090)	(0.097)	(0.107)	(0.075)	(0.090)
EMU_4after	0.403**	0.141+	0.544**	-0.187+	0.256**	0.069	0.432**	-0.037	0.395**
	(0.121)	(0.077)	(0.098)	(0.103)	(0.099)	(0.106)	(0.117)	(0.079)	(0.099)
EMU_5after	0.409**	0.158+	0.567**	-0.255*	0.281**	0.026	0.433**	-0.067	0.367**
	(0.124)	(0.080)	(0.100)	(0.104)	(0.099)	(0.107)	(0.120)	(0.082)	(0.102)
Custrict	1.000**	-0.020	0.980**	0.042	0.183+	0.225*	0.974**	-0.042	0.932**
	(0.143)	(0.093)	(0.170)	(0.103)	(0.099)	(0.106)	(0.144)	(0.091)	(0.168)
Regional	0.720**	0.423**	1.144**	-0.019	0.213**	0.194**	0.648**	0.434**	1.082**
	(0.109)	(0.073)	(0.115)	(0.040)	(0.038)	(0.041)	(0.111)	(0.073)	(0.115)
EU	-0.490**	0.253**	-0.237**	0.093**	0.179**	0.272**	-0.525**	0.314**	-0.211**
	(0.080)	(0.052)	(0.084)	(0.035)	(0.034)	(0.036)	(0.081)	(0.052)	(0.075)
EU_Trend	-0.055**	0.028**	-0.027**	-0.010**	0.027**	0.017**	-0.055**	0.025**	-0.030**
	(0.005)	(0.003)	(0.005)	(0.002)	(0.002)	(0.002)	(0.005)	(0.003)	(0.005)
observations	215121	215121	215121	215121	215121	215121	215121	215121	215121
# of country pair FE				13600	13600	13600			
R_Squared	0.65	0.57	0.74	0.39	0.25	0.57	0.67	0.59	0.76

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

The model is estimated by ordinary least squares with robust standard errors clustered in export pair level. The dependent variables 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, $EMU_{jm,t}$.over various leads and lags. Also included are dummies for European Union and trend, $EU_{jm,t}$ and $EUTrend_{jm,t}$. Also included but not shown are regressors 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*, a dummy variable indicating whether the two countries had a free trade agreement at time *t*, the logarithm of distance between country *j* and *m*, a common language dummy, a land border dummy. Also included is a time effect, *t* and two vectors of dummy variables indicating exporter and importer fixed effects.

Table 4: Gravity regressions with EMU lag and lead indicators, full sample, with time-varying measures of European market integration, country-year fixed effects

Dependent	*Controls for Exchange Rate Volatility and Regime*			*Index of European Market Integration*		
Variable	**(1) Extensive margin**	**(2) Intensive margin**	**(3) Overall trade**	**(4) Extensive margin**	**(5) Intensive margin**	**(6) Overall trade**
EMU_7ahead	0.105	-0.119*	-0.013	0.138+	-0.138**	0.001
	(0.087)	(0.054)	(0.074)	(0.081)	(0.053)	(0.070)
EMU_6ahead	0.142	-0.141+	0.000	0.145+	-0.147**	-0.001
	(0.090)	(0.055)	(0.074)	(0.083)	(0.053)	(0.071)
EMU_5ahead	0.130	-0.147**	-0.017	0.107	-0.139**	-0.033
	(0.091)	(0.056)	(0.073)	(0.081)	(0.053)	(0.069)
EMU_4ahead	0.311**	-0.219**	0.092	0.312**	-0.219**	0.093
	(0.090)	(0.061)	(0.077)	(0.095)	(0.064)	(0.076)
EMU_3ahead	0.375**	-0.249**	0.126	0.330**	-0.227**	0.103
	(0.091)	(0.061)	(0.077)	(0.094)	(0.064)	(0.076)
EMU_2ahead	0.400**	-0.221**	0.179*	0.298**	-0.191**	0.106
	(0.095)	(0.067)	(0.080)	(0.096)	(0.067)	(0.076)
EMU_1ahead	0.452**	-0.168*	0.284*	0.311**	-0.128+	0.183*
	(0.099)	(0.069)	(0.085)	(0.096)	(0.068)	(0.079)
EMU_0ahead	0.506**	-0.229**	0.277**	0.337**	-0.153*	0.184*
	(0.102)	(0.069)	(0.083)	(0.095)	(0.068)	(0.077)
EMU_1after	0.548**	-0.134+	0.414**	0.342**	-0.042	0.300**
	(0.106)	(0.073)	(0.087)	(0.095)	(0.070)	(0.079)
EMU_2after	0.575**	-0.143+	0.7433**	0.324**	-0.030	0.294**
	(0.107)	(0.073)	(0.089)	(0.094)	(0.070)	(0.078)
EMU_3after	0.605**	-0.131+	0.474**	0.302**	0.004	0.307**
	(0.110)	(0.075)	(0.092)	(0.093)	(0.071)	(0.079)
EMU_4after	0.428**	-0.040	0.387**	0.079	0.116	0.195*
	(0.119)	(0.080)	(0.101)	(0.106)	(0.078)	(0.088)
EMU_5after	0.430**	-0.072	0.358**	0.025	0.110	0.135
	(0.123)	(0.083)	(0.104)	(0.104)	(0.078)	(0.087)
EU	-0.526**	0.309**	-0.217**	-0.771**	0.393**	-0.378**
	(0.081)	(0.052)	(0.075)	(0.109)	(0.065)	(0.089)
EU trend	-0.055**	0.025**	-0.030**			
	(0.005)	(0.003)	(0.005)			
Direct Peg	0.072	0.223**	0.295**			
	(0.070)	(0.059)	(0.083)			
Indirect Peg	-0.028	-0.073**	-0.101**			
	(0.027)	(0.023)	(0.033)			
Exch. Rate Volatility	-0.101**	0.162**	0.064	-0.102**	0.167**	0.065
	(0.038)	(0.027)	(0.040)	(0.039)	(0.028)	(0.040)
Market Integ. Index				-0.024**	0.013**	-0.011**
				(0.004)	(0.003)	(0.004)
observations	215116	215116	215116	215121	215121	215121
R_Squared	0.67	0.59	0.76	0.67	0.59	0.76

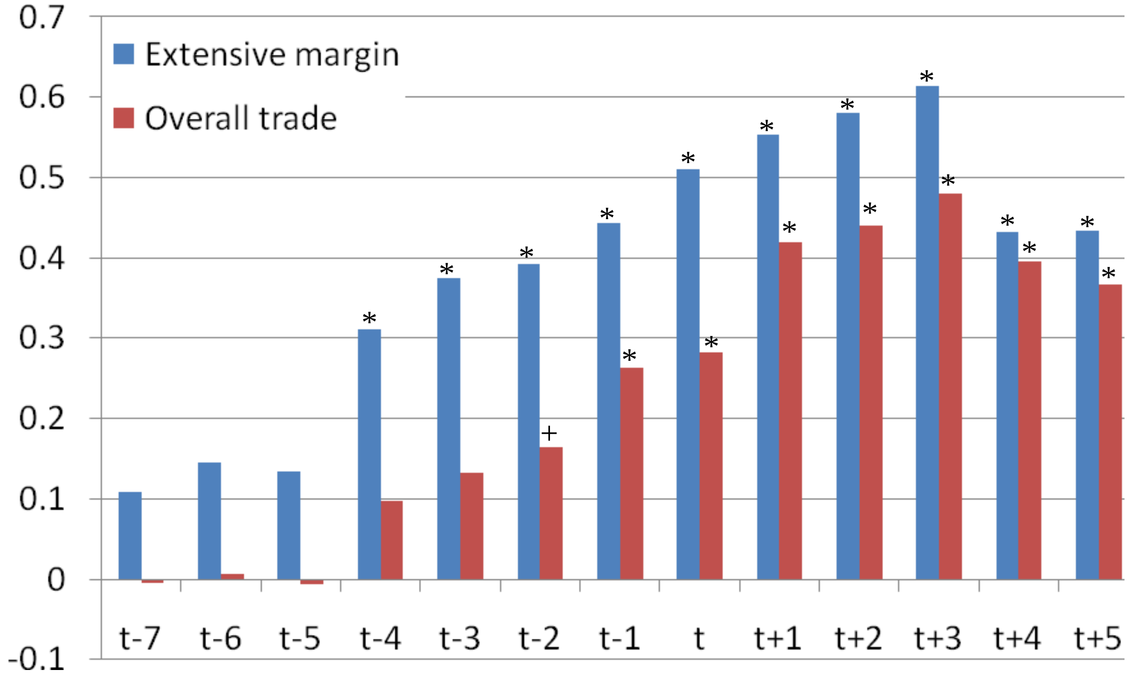
** indicates significance at 1% level, * at 5%, and + at 10%.
Model specification and variable definitions are the same as previous table, with the addition of dummy variables for exchange rate regime, a measure of exchange rate volatility, and a measure of EU market integration.

Fig. 1. Average extensive margin measure for
EMU country pairs

Authors computations using definition of extensive margin in equation (1), and using data from the NBER-UN World Trade Data set, developed by Rob Feenstra and Robert Lipsey, documented in Feenstra et al. (2005). Unweighted average taken among EMU country pairs.

Fig. 2. EMU indicators over time

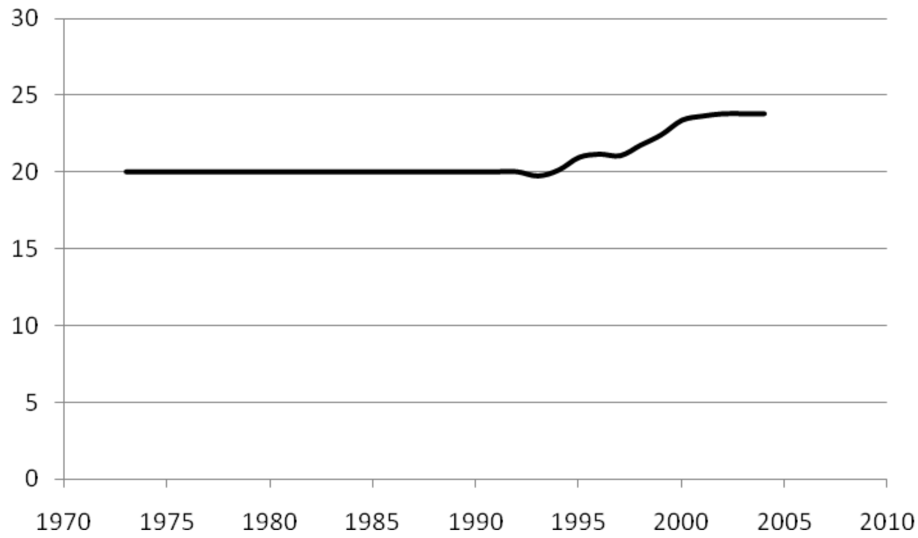
(Full country sample, time-varying fixed effects)



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

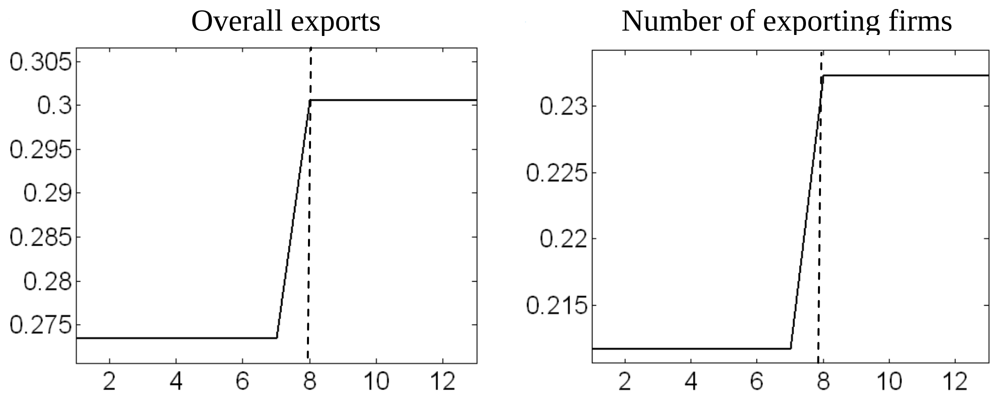
This figure plots the point estimates from the regressions in Table 3, for the case of time-varying fixed effects.

Fig 3. Index of EU market integration



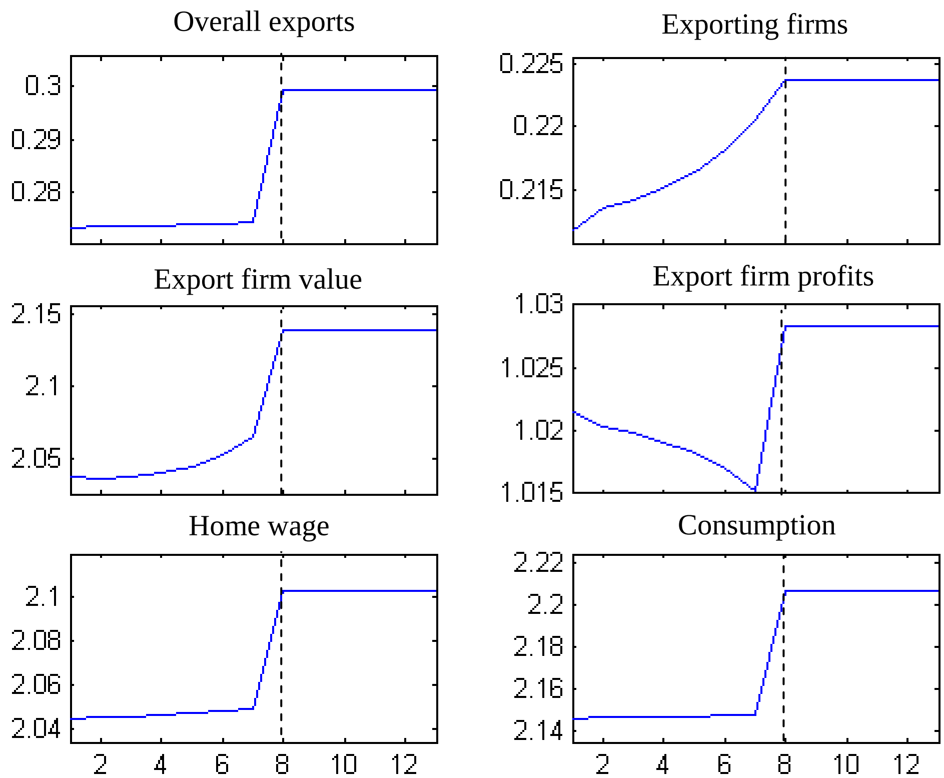
The Internal Market Index created by the European Commission is a composite of 12 indicators such as telecommunication costs and foreign direct investment flows. We use the summary of this measure created by Berger and Nitsch (2008), which sets the initial value in the base year 1992 at 20, and adds ten points for each doubling of the index.

Fig 4: Response to an anticipated permanent symmetric fall in iceberg trade costs, model with constant sunk cost



Shock: fall in iceberg cost from 0.2 to 0.1 in period 8, announced in period 1.
Benchmark parameter settings, except $\chi = 0$.

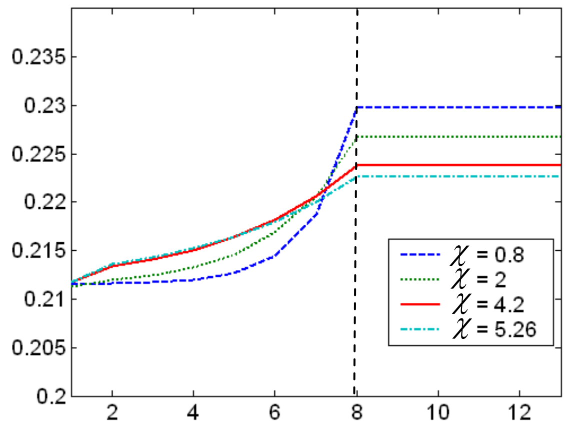
Fig 5: Response to an anticipated permanent symmetric fall in iceberg trade costs, benchmark model



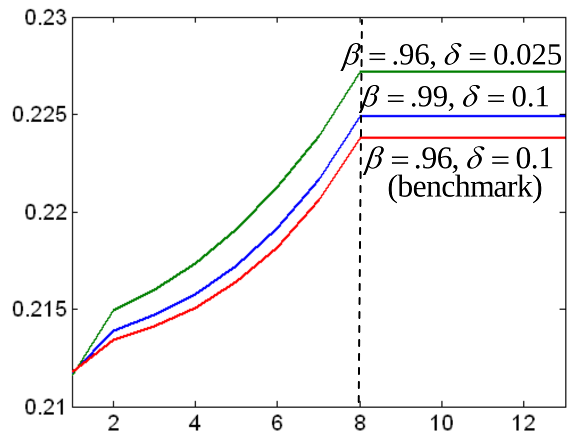
Shock: fall in iceberg cost from 0.2 to 0.1 in period 8, announced in period 1.

Fig 6: Sensitivity analysis: response in number of exporting firms to anticipated permanent symmetric fall in iceberg trade costs

a) Alternative calibrations of sunk cost elasticity (χ)



b) Alternative discounting parameters



c) Alternative specification of sunk cost as quadratic adjustment cost

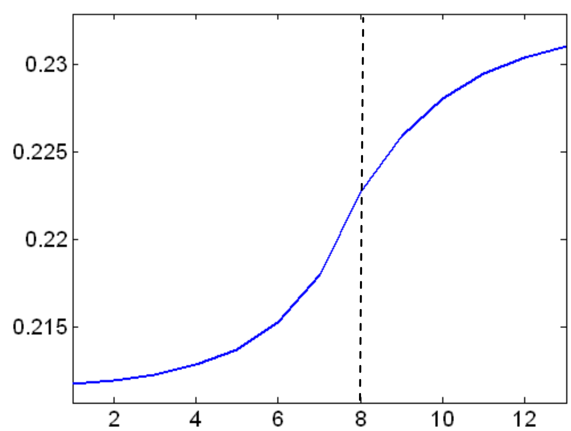
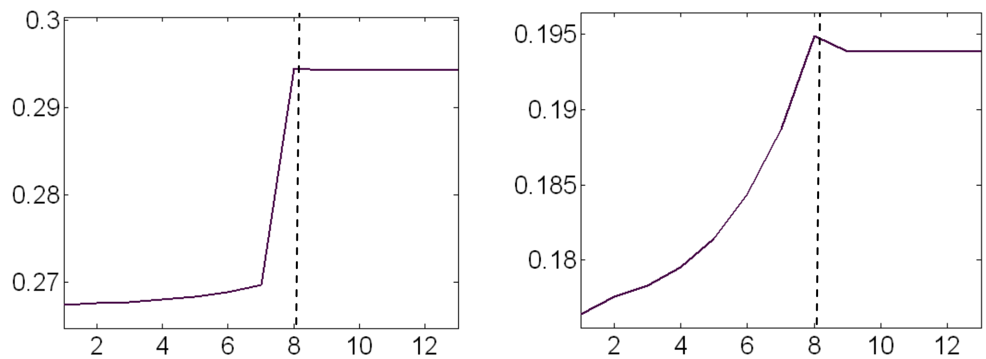


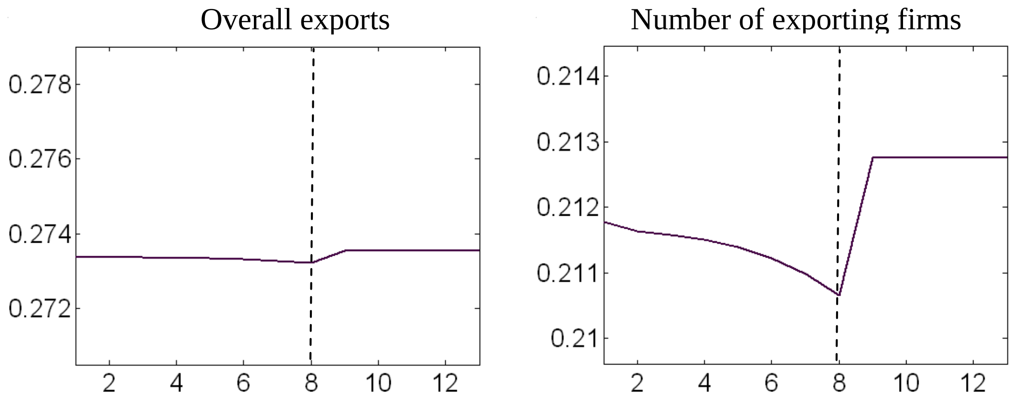
Fig 7. Overshooting in extensive margin under ρ = 0.10

Overall exports | Number of exporting firms



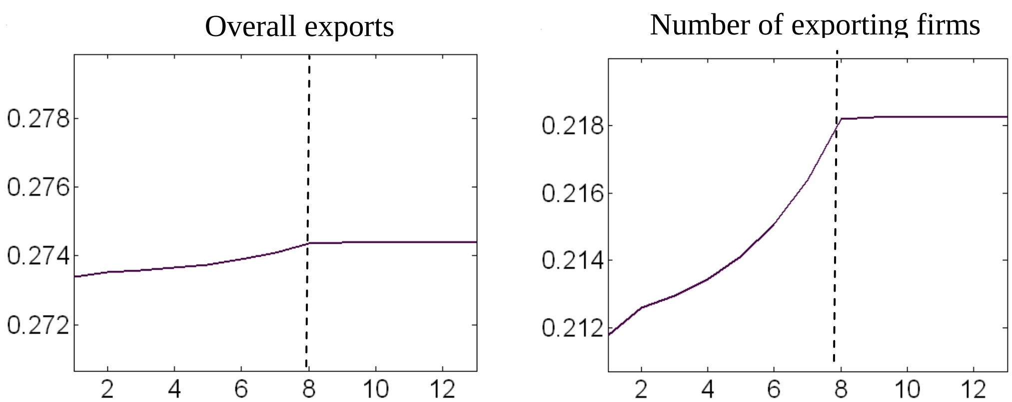
Shock: fall in iceberg cost from 0.2 to 0.1 in period 8, announced in period 1.

Fig. 8. Response to an anticipated future permanent fall in sunk cost



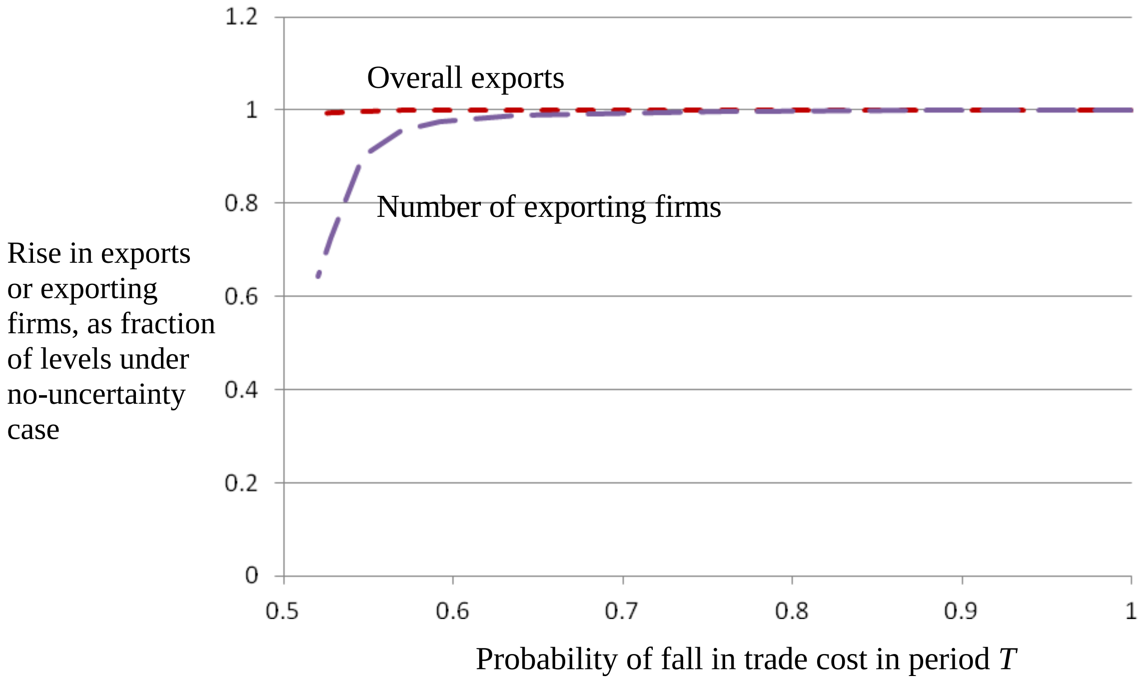
Shock: fall in average sunk costs $\overline{K_H}$ and $\overline{K_F}$ by 5% in period 8, announced in period 1.

Fig 9. Response to an anticipated future symmetric fall in fixed cost



Shock: fall in fixed cost $F_{H,t}$ and $F_{F,t}$ by 5% in period 8, announced in period 1.

Fig.10. Effect of uncertainty



Note: The figure plots the rise in exports and in the extensive margin in period T=8, each scaled as a fraction of the rise under the case of no uncertainty. So a value of unity means the variable rises as much under uncertainty as under certainty. The bottom axis indicates the probability that the draw of stochastic iceberg trade costs in period T will be lower than period T-1. So a value of 1 on the horizontal axis means no uncertainty about the drop in trade costs in period T, while a value of 0.5 indicates there is a 50% chance trade costs will fall in period T.

Appendix:

A1. Derivation of equation (32) in the text

Beginning with the entry condition (27) in the main text:

$$K_{H,t}\frac{W_t}{P_t A} = E_t\left(\beta(1-\delta)\right)\frac{u_{D,t+1}}{u_{D,t}}\left[K_{H,t+1}\frac{W_{t+1}}{P_{t+1}A} + \pi_{HX,t+1}(i)\right],$$

substitute in for export profits from (21)

$$\pi_{HX,t}(i) = \left(p_{HX,t}(i) - \frac{W_t}{A\left(1-\tau_{H,t}\right)}\right)\frac{d_{HX,t}(i)}{P_t} - \frac{W_t}{AP_t}F_{H,t}$$

where demands for identical individual goods come from (8)

$$d_{HX,t}(i) = \frac{D_{HX,t}}{n_{HX,t}^{\frac{\mu}{\mu-1}}},$$

and use the foreign counterpart of (13) to write overall demand for exports as a function of overall foreign consumption

$$D_{HX,t} = (1-\theta)\left(P_{HX,t} / P^*_t\right)^{-\phi} D^*_t,$$

to get

$$E_t\left(\beta(1-\delta)\right)\frac{u_{D,t+1}}{u_{D,t}}\left(\left(p_{HX,t+1}(i) - \frac{W_{t+1}}{A\left(1-\tau_{H,t+1}\right)}\right)\frac{(1-\theta)\left(P_{HX,t+1} / P^*_{t+1}\right)^{-\phi} D^*_{t+1}}{P_{t+1}n_{HX,t+1}^{\frac{\mu}{\mu-1}}} - \frac{W_{t+1}}{AP_{t+1}}F_{H,t+1}\right)$$

$$= K_{H,t}\frac{W_t}{P_t A} - E_t\left(\beta(1-\delta)\right)\frac{u_{D,t+1}}{u_{D,t}}K_{H,t+1}\frac{W_{t+1}}{P_{t+1}A}.$$

Next substituting for prices, use the overall export price index from the counterpart of (11)

$$P_{HXt} = n_{HX,t}^{\frac{1}{1-\mu}}p_{HX,t}(i)$$

and individual good pricing from (23)

$$p_{HX,t}(i) = \frac{\mu}{\mu-1}\frac{W_t}{A\left(1-\tau_{H,t}\right)}$$

to find

$$E_t\left(\beta(1-\delta)\right)\frac{u_{D,t+1}}{u_{D,t}}\left(\left(\frac{\mu}{\mu-1}\frac{W_{t+1}}{A\left(1-\tau_{H,t+1}\right)}-\frac{W_{t+1}}{A\left(1-\tau_{H,t+1}\right)}\right)\frac{(1-\theta)\left(n_{HX,t+1}{}^{\frac{1}{1-\mu}}\frac{\mu}{\mu-1}\frac{W_{t+1}}{A\left(1-\tau_{H,t+1}\right)}/P^{*}{}_{t+1}\right)^{-\phi}D^{*}{}_{t+1}}{P_{t+1}n_{HX,t+1}{}^{\frac{\mu}{\mu-1}}}\right)$$

$$=K_{H,t}\frac{W_t}{P_tA}-E_t\left(\beta(1-\delta)\right)\frac{u_{D,t+1}}{u_{D,t}}K_{H,t+1}\frac{W_{t+1}}{P_{t+1}A}+E_t\left(\beta(1-\delta)\right)\frac{u_{D,t+1}}{u_{D,t}}\frac{W_{t+1}}{AP_{t+1}}F_{H,t+1}$$

Simplify and solve for number of firms (imposing symmetry across countries, which holds for all our experiments):

$$n_{HX,t+1}=\left[\frac{E_t\left(\beta(1-\delta)\right)\frac{u_{D,t+1}}{u_{D,t}}\left((1-\theta)\mu^{-\phi}\left(\frac{1}{\mu-1}\frac{W_{t+1}}{AP_{t+1}}\right)^{1-\phi}\left(1-\tau_{H,t+1}\right)^{\phi-1}D^{*}{}_{t+1}\right)}{K_{H,t}\frac{W_t}{AP_t}-E_t\left(\beta(1-\delta)\right)\frac{u_{D,t+1}}{u_{D,t}}K_{H,t+1}\frac{W_{t+1}}{AP_{t+1}}+E_t\left(\beta(1-\delta)\right)\frac{u_{D,t+1}}{u_{D,t}}\frac{W_{t+1}}{AP_{t+1}}F_{H,t+1}}\right]^{\frac{\mu-1}{\mu-\phi}}.$$

Note that $n_{HX,t+1}$ is determined already in period *t*, and can be pulled out from under the expectations operator.

A2. Additional robustness checks

Here we report on the robustness of our results to using alternative country samples. In addition to the European Union Sample of 15 countries, we considered adding 3 European countries not in the EU (Iceland, Norway, and Switzerland), or alternatively adding 3 non-European countries (United States, Canada, Japan), and a sample of all developed countries in the data base. Our all-country sample nests each of these subsamples. For each sample we estimated our basic regression, as well as the specification including exchange rate volatility and exchange rate regime indicators, and a specification including the European market integration index. In addition, we also estimated a specification that included dynamic dummies for EU membership before and after EU implementation in 1992, analogous to what we estimate for EMU membership in the benchmark specification. Table A1 summarizes the robustness of our empirical claims for the various samples and regression specifications. Our main conclusions, regarding an early and significant extensive margin response are robust for almost all samples and specifications, as is the result that the extensive margin effect decays after EMU implementation. The results regarding the effects of EMU on overall trade are somewhat less robust, as is the result that the magnitude of extensive margin effects is larger than that for overall trade.

Table A1: Robustness Checks

	Extensive margin effects of EMU: Significant pos. before t	Significant positive in t	Decline after t	EM larger than overall in t	EM earlier than overall	Overall trade effects of EMU: Significant pos. before t	Significant positive in t
<u>EU15 Sample</u>							
Benchmark	CFE,CPFE,CYFE	CFE,CPFE,CYFE	CFE,CPFE,CYFE	CPFE	CPFE	CFE,CYFE	CFE,CYFE
Exch. Rates	CFE,CPFE,CYFE	CFE,CPFE	CFE,CPFE,CYFE	CPFE	CPFE	CFE,CYFE	CFE
<u>EU15+3 Sample</u>							
Benchmark	CFE,CPFE,CYFE	CFE,CPFE,CYFE	CFE,CPFE,CYFE	CPFE	CFE,CPFE	CFE,CPFE,CYFE	CFE,CPFE,CYFE
Exch. Rates	CFE,CPFE,CYFE	CFE.CPFE,CYFE	CFE,CPFE,CYFE	CPFE	CFE,CPFE	CFE,CYFE	CFE,CPFE,CYFE
EU Dynamics	CFE,CPFE,CYFE	CFE,CPFE,CYFE	CFE,CPFE,CYFE	CPFE,CYFE	CPFE	CFE,CPFE,CYFE	CFE,CPFE,CYFE
EU Index	CFE,CPFE,CYFE	CPFE,CYFE	CFE,CPFE,CYFE	CPFE	CFE,CPFE, CYFE	CFE,CPFE,CYFE	CFE,CPFE,CYFE
<u>18 developed Sample</u>							
Benchmark	CFE,CPFE,CYFE	CFE,CPFE,CYFE	CFE,CPFE,CYFE	CPFE	CFE,CPFE, CYFE	CFE,CYFE	CFE,CYFE
Exch. Rates	CFE,CPFE,CYFE	CFE,CPFE	CFE,CPFE,CYFE	CPFE	CFE,CPFE	CFE,CYFE	CFE,CPFE,CYFE
EU Dynamics	CFE,CPFE,CYFE	CFE,CPFE	CFE,CPFE,CYFE	CPFE	CPFE,CYFE	CFE,CPFE, CYFE	CPFE
EU Index	CPFE	CPFE	CFE,CPFE,CYFE	CPFE	CFE,CPFE,CYFE	CYFE	CPFE
<u>All Developed Sample</u>							
Benchmark	CFE,CPFE,CYFE	CFE,CPFE,CYFE	CFE,CPFE,CYFE	CPFE	CFE,CPFE	CFE,CPFE,CYFE	CFE,CPFE,CYFE
Exch. Rates	CFE,CPFE,CYFE	CFE,CPFE,CYFE	CFE,CPFE,CYFE	CPFE	CFE,CPFE	CFE,CYFE	CFE,CPFE,CYFE
EU Dynamics	CFE,CPFE,CYFE	CFE,CPFE	CFE,CPFE,CYFE	CPFE	CPFE	CFE,CPFE,CYFE	CPFE
EU Index	CFE,CPFE,CYFE	CPFE	CFE,CPFE,CYFE	CPFE	CFE,CPFE	CFE,CPFE,CYFE	CFE,CPFE
<u>All Countries</u>							
Benchmark	CFE,CPFE,CYFE	CFE,CPFE,CYFE	CFE,CPFE,CYFE	CFE,CPFE,CYFE	CFE,CPFE,CYFE	CFE	CFE
Exch. Rates	CFE,CPFE,CYFE	CFE,CPFE,CYFE	CFE,CPFE,CYFE	CFE,CPFE,CYFE	CFE,CPFE,CYFE	CFE	CFE
EU Dynamics	CPFE	CPFE	CFE,CPFE,CYFE	CPFE	CPFE	--	--
EU Index	CFE,CPFE,CYFE	CFE,CPFE,CYFE	CFE,CPFE,CYFE	CFE,CPFE,CYFE	CFE,CPFE,CYFE	CPFE	--

Rows represent various country samples and regression specifications. Columns represent our various empirical claims. Each cell represents a set of 3 estimations (CFE for country fixed effects, CPFE for country pair fixed effects, CYFE for country year fixed effects), and records which estimation was robust for that empirical claim for that sample/specification. We consider 5 samples. The EU15 and All Countries samples are discussed in the main paper; EU15+3 adds U.S., Japan, and Canada; 18 major developed and the set of all developed countries in our data set. Note that results for the EU15 and all country samples can vary slightly from those in the preceding tables, as the estimations here include EMU dynamic dummies for all years in the sample, whereas estimations reported in the tables limit dummies to the leads and lags listed in the table