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Export Decisions and International Business Cycles *

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ABSTRACT

Using firm level data, Bernard and Jensen (1995, 1999, 2001) find that exporters are bigger and more productive than non-exporters. These studies also find that the identity of exporting firms changes over time and that fixed entry and participation costs influence firm's decision to enter and exit export markets. This paper develops a model with firm level heterogeneity and export dynamics to study the propagation of international business cycles. We find that the export decision of firms lead to greater comovement in economic activity across countries and offers a potential resolution to both the consumption correlations and international comovements puzzles.

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1. Introduction

A number of features of the comovement of business cycles across countries are difficult to explain in theory.[1] In this paper we focus on two of these features. The first is the observation that consumption across countries is less correlated than output across countries. This is contrary to what models with risk sharing predict and is often described as the *consumption correlations puzzle.* The second feature of the data is that both employment and investment are positively correlated across countries. Standard single or multiple good models generate low or negative international comovements of investment and employment as in these models production is shifted across countries to take advantage of better productive opportunities. This observation is referred to as the *international comovements puzzle.* To address these puzzles, and the international propagation of business cycles, we focus on fixed costs of international trading which give rise to firm level dynamics in the export sector.

Our emphasis on firm level dynamics is motivated by recent empirical studies of the characteristic of exporting and non-exporting firms. Two aspects of these studies suggest that the dynamics of the export sector may provide an important channel for the international transmission of business cycles. First, there is evidence that exporting firms more productive and much bigger, in terms of employment and capital, than non-exporters. Second, the identity of exporting firms changes substantially over time. This evidence has been interpreted to imply that firms face fixed costs to export to foreign markets and that the value of participating in foreign markets varies over time. In this paper, we explore the implications of this churning of the most productive and largest firms in the economy for the international transmission of business cycles.

We construct a dynamic general equilibrium model with firm level export dynamics. Three departures from the standard international business cycle model are necessary to generate firm level export dynamics. First, we assume that in each country there is a continuum of monopolistically competitive firms producing differentiated intermediate goods. Second, we assume that firms are heterogenous in their technology and are subject to idiosyncratic technology shocks. Third, we assume that there are fixed costs of entering and participating in export markets. These fixed costs are of two types. There are *export penetration* costs which are the large, up-front fees that firms incur to establish a presence in foreign markets. Next, there are *continuation costs* which firms incur to maintain their position in foreign markets. We think of these fees as corresponding to the

[1] Baxter (1995) and Obstfeld and Rogoff (2001) provide comprehensive summaries of the puzzles in international macroeconomics.

costs of establishing and maintaining foreign marketing campaigns and distribution channels. These features of the model give rise to characteristics of exporters and non-exporters which match the data. Moreover, by endogenizing the division between traded and non traded goods in the economy, these features introduce an extensive margin into the pattern of trade between countries.

Our main finding is that a model with firm level heterogeneity calibrated to match certain characteristics of export sector dynamics does not exhibit the consumption correlation or international comovement puzzles. This finding can be explained by considering the impact of a positive home country-specific productivity shock. This shock encourages an increase in both home consumption and capital accumulation. Unlike standard models, this leads to an increase in demand for the varieties of existing foreign exporters as well new varieties of foreign intermediates. The stock of foreign products available at home rises through increased entry by new foreign exporters and reduced exit by current exporters. Quantitatively, the exit margin is largest as firms with current low productivity defer exit. The increased demand at home for foreign varieties leads to an increase in employment and output as well as an investment boom in the foreign export sector. To finance this investment in the foreign export sector, foreign consumption declines on impact. It is this decline in consumption on impact which gives rise to a positive, but low consumption correlation across countries.

Many researchers have studied the international transmission of business cycles. Among the papers that focus on real factors as the source of fluctuations, our approach is most closely related to Backus, Kehoe and Kydland (1992), Stockman and Tesar (1995), Obstfeld and Rogoff (2000) and Betts and Kehoe (2002). To different degrees, these papers investigate the role of frictions in the goods market for the propagation of business cycles[2]. Our approach here differs in that we concentrate on the role of fixed international trading costs on the export decisions of heterogenous firms. Previous work by Baldwin (1988), Baldwin and Krugman (1989) and Dixit (1989a,b) study the role of sunk entry costs on the export behavior of firms in partial equilibrium environments. These papers were developed to study export hysteresis following the swing in the value of the dollar in the 80's. Recent work by Bernard, Eaton, Jensen and Kortum (2000) and Melitz (2003) also consider the role of firm heterogeneity in an international context. These papers focus on the pattern of trade and welfare gains from trade liberalization and do not consider aggregate fluctuations. Finally, recent work by Evenett and Venables (2002), Hummels and Klenow (2002)

[2] Another approach has focused on frictions in international asset markets (see Baxter and Crucini (1995), Heathcoate and Perri (2001) and Kehoe and Perri (2002)).

and Kehoe and Ruhl (2002) study the growth in trade through the intensive and extensive margins.

The paper is organized as follows. The next section discusses the evidence of exporter characteristics in the data. Section 3 develops a two country dynamic general equilibrium model with export penetration and continuation costs. Section 4 discusses the quantitative implications of the model. Section 5 explores the sensitivity of the model to the structure of asset trade, aggregate shocks, firm-level shocks, and preferences. Section 6 concludes. All tables and figures are at the end of the paper.

2. Exporter characteristics and dynamics

We begin by summarizing some recent evidence about the characteristics of exporters. This evidence is drawn from plant and firm-level data in several countries and documents a number of margins along which exporters differ from non-exporters. Among other dimensions, exporters tend to have higher productivity, higher levels of output, and use more capital and labor inputs. Using the Longitudinal Research Database (LRD) of the Bureau of Census from 1984 to 1992 data, Bernard and Jensen (1999) find that U.S. exporters are 12 percent to 18 percent more productive, employ 77 percent to 95 percent more workers, use 13 percent to 20 percent more capital per worker and produce 104 percent to 115 percent more output than non-exporters.[3]

Second, there is substantial entry and exit into foreign markets as many firms that export in one period stop exporting in the next period and vice versa. Using a balanced panel of firms continuously present in the U.S. Census Bureau's Annual Survey of Manufacturers (ASM) from 1984 to 1992, Bernard and Jensen (2001) show that the fraction of last period's non-exporters that transition to exporting, which we term the *starter* ratio, is about 13.9 percent per year. The fraction of last period's exporters that transition to non-exporter status, which we term the *stopper* ratio, is about 12.6 percent on average. The starter and stopper ratios change over time leading to ifluctuations in the ratio of exporters among all firms, which we term the *exporter* ratio. Since the starter ratio is slightly higher than stopper ratio, the exporter ratio exceeds 50 percent. During this period, the exporter ratio increases from 47.6 percent of the firms in 1984 to 54.04 percent in 1992.[4] Bernard and Jensen (2001) attribute much of the growth in exporter ratio to a decline in

[3] The LRD is not a representative sample of manufacturing firms but is biased towards larger firms. Consequently, this database tends to understate the differences between exporters and non-exporters compared to the Census of Manufactures.

[4] Since the starter and stopper ratios can be considered transition probabilities in export status, a higher starter ratio than stopper ratio does not necessarily mean that the exporter ratio is increasing all the time. If the starter and stopper ratios are n_0 and n_1 all the time, the exporter ratio converges to $\frac{n_0}{n_0+n_1}$.

the stopper ratio.

German and Colombian manufacturing data also show significant turnover ratios in export status. Using annual manufacturing plant-level data from 1978 to 1992 in Lower Saxony, Germany, Bernard and Wagner (1998) find that on average, starter and stopper ratios are about 4.14% and 5.51%, respectively. In this region, the exporter ratio is only about 41.2% on average. Roberts and Tybout (1997) use annual data of Colombian manufacturing Census data from 1981 to 1989 to find that on average, the starter and stopper ratios are about 3.3% and 11.5%, respectively. The exporter ratio is about 11.8% on average. These findings are reproduced in Table 1.

The evidence about exporter characteristics and dynamics has been interpreted to imply that there are significant export penetration and continuations costs to international trade which influence the exporting decisions of firms.[5] These fixed costs are attributed to higher foreign marketing and distribution costs, additional bureaucratic procedures, and required changes in product characteristics to tailor products to the tastes of foreign consumers and to satisfy government regulations. Using annual firm level data on Colombian chemical producers from 1982 to 1991, Das, Roberts and Tybout (2001) estimate that export penetration costs account for between 18.4 percent and 41.2 percent of the annual value of a firms exports. In 1999 U.S. dollars, these costs are estimated to be between $730,000 and $1.6 million, depending on plant size. The continuation costs are considerably smaller and are estimated to be about 1 percent of the annual value of exports. These findings suggest that fixed costs of entry and continuation matter for the export decision of firms. This is a feature which is often overlooked in the previous literature on international business cycle.

3. Model

We develop a two-country model with infinitely lived consumers and heterogeneous firms to study the international transmission of business cycles. The production side of the model is developed to be consistent with the characteristics and dynamics of exporters described in the previous section. This requires taking a stand on what determines a firm. Our view is that a firm is associated with a unique variety of differentiated good with a production process that is subject to idiosyncratic technology shocks.

There are two countries, *home* and *foreign*. Each country is populated by a large number of identically, infinitely lived consumers. In each period of time, the economy experiences an event

[5] Roberts and Tybout (1997), Bernard and Wagner (1998), Aw, Chung an Roberts (1998), Bernard and Jensen (1999) and Das, Roberts and Tybout (2001) use Colombian, German, Taiwan, and Korean plant or firm-level manufacturing data, respectively. They commonly find evidence of large fixed export costs.

s_t. Let $s^t = (s_0, \cdots, s_t)$ denote the history of events from period 0 up to and including period t. The probability of a history s^t, conditional on the information available at period 0, is defined as $\pi(s^t|s^0)$. The initial realization of an event at period 0, s_0, is given.[6]

In each country there is a large number of monopolistically competitive firms each producing a differentiated intermediate good. The many intermediate good producers are normalized to a continuum with unit mass and are indexed $i \in [0, 1]$. An intermediate good producer uses capital and labor inputs to produce its intermediate goods. Firms differ in terms of total factor productivity, capital and the markets they serve. All firms sell their product in their own country but only some firms export their good abroad. When an intermediate good producer exports goods abroad, the producer incurs some international trading costs. The costs depends on the producer's export status in the previous period. There is a (relatively) high initial entry cost τ_0 that must be borne to gain entry into the export market. In subsequent periods, to continue exporting firms incur a a lower but nonzero period-by-period fixed continuation cost τ_1. If a firm does not pay this continuation cost, then it ceases to export. In future periods, the firm can only begin exporting by incurring the entry cost τ_0 again.

In each country, competitive final goods producers purchase intermediate goods from those firms actively selling in that country. The cost of exporting implies that the set of goods available to competitive final goods producers differs across countries. The entry and exit of exporting firms implies that the set of intermediate goods available across countries is changing over time. Competitive final good producers use home and foreign intermediate goods as inputs to production.[7] The final goods are used for domestic consumption or investment.

We assume that there are no economies of scale to exporting. In particular, it is not possible for a single firm to incur the fixed cost of exporting and then export multiple different varieties of intermediate goods. We take the view that τ_0 represents the cost of entering the foreign market per variety. In practice, these fixed costs represent those costs associated with tailoring a product to the standards and taste of foreign agents, establishing marketing and distribution networks, and learning about bureaucratic and administrative details in foreign markets. For diverse goods, it is unlikely exporting in one good reduces the fixed costs of exporting a second good.

In this economy, there exists a complete set of one period state contingent nominal bonds

[6] The history of events, s^t, maps onto the state of the world.

[7] Final good production technology does not require capital or labor inputs. The final good production technology regulates the preferences of a country on home and foreign goods.

denominated in the home currency. Let $B\left(s^{t+1}, s^t\right)$ denote the home consumers holdings of a bond purchased in state s^t with payoff in state s^{t+1}. Let $B^*\left(s^{t+1}, s^t\right)$ denote the foreign consumers holding of this bond. The state contingent bond $B(s^t)$ pays 1 unit of home currency if s^t occurs, and 0 otherwise. Let $Q(s^{t+1}|s^t)$ denote the nominal price of the state contingent bond $B(s^{t+1})$ given s^t. All the intermediate and final good producers are owned by domestic consumers. It is assumed that these ownership claims can not be traded.

A. Consumers Problem

Home consumers choose consumption, labor and bond holdings to maximize their utility:

$$\max \sum_{t=0}^{\infty} \sum_{s^t} \beta^t \pi\left(s^t|s_0\right) U\left[c\left(s^t\right), l\left(s^t\right)\right],$$

subject to the sequence of budget constraints,

$$P(s^t)c(s^t) + \sum_{s^{t+1}} Q(s^{t+1}|s^t)B(s^{t+1}) \leq P(s^t)w(s^t)l(s^t) + B(s^t) + \Pi(s^t) + P(s^t)T(s^t),$$

where $c(s^t)$ and $l\left(s^t\right)$ are the final good consumption and labor, respectively; $P(s^t)$ and $w\left(s^t\right)$ denote the price level and wage rate; $\Pi(s^t)$ is the sum of profits of the home country's intermediate good producers; and $T(s^t)$ is a lump sum transfer from the government. The discount factor is β.

The problem of foreign consumers is analogous to this problem. Prices and allocations in the foreign country are represented with an asterisk. To be clear, money has no role in this economy. However, we do use the local currency as a unit of account so that the foreign budget constraint is expressed as

$$P^*(s^t)c^*(s^t) + \sum_{s^{t+1}} \frac{Q(s^{t+1}|s^t)}{e(s^t)} B^*(s^{t+1}) \leq P^*(s^t)W^*(s^t)L^*(s^t) + \frac{B^*(s^t)}{e(s^t)} + \Pi^*(s^t) + P^*(s^t)T^*(s^t),$$

where * denotes the foreign variables and $e(s^t)$ is the nominal exchange rate.

The first order conditions for home consumers' utility maximization problems are

$$-\frac{U_l(s^t)}{U_c(s^t)} = w(s^t),$$

$$(1) \qquad Q(s^{t+1}|s^t) = \beta\pi(s^{t+1}|s^t)\frac{U_c(s^{t+1})}{U_c(s^t)}\frac{P(s^t)}{P(s^{t+1})},$$

where $U_c(s^t)$, and $U_l(s^t)$ denote the derivatives of the utility function with respect to its arguments.

The price of the state contingent bond is standard. With arbitrage, the complete asset markets assumption implies that the real exchange rate, $q(s^t)$, is proportional to the ratio of marginal utility of consumption at foreign to that at home or

$$(2) \quad q(s^t) = \frac{e(s^t)P^*(s^t)}{P(s^t)} = \kappa \frac{U_c^*(s^t)}{U_c(s^t)},$$

where $\kappa = q(s^0)U_c(s^0)/U_c^*(s^0)$.[8]

B. Final Good Producers

In the home country, final goods are produced using only home and foreign intermediate goods. A final good producer can purchase from any of the home intermediate good producers, but can only purchase from those foreign intermediate good producers that are actively selling in the home market. The set of foreign firms actively selling in the home country is denoted by $\mathcal{E}^*(s^t)$, where $i \in \mathcal{E}^*(s^t)$ if the i_{th} firm is a foreign exporter in s^t.

The production technology of the firm is given by a constant elasticity of substitution (henceforth CES) function

$$(3) \quad D(s^t) = \left\{ a_1 \left[\int_0^1 y^d(h,i,s^t)^\theta di \right]^{\frac{\rho}{\theta}} + a_2 \left[\int_0^1 y^d(f,i,s^t)^\theta di \right]^{\frac{\rho}{\theta}} \right\}^{\frac{1}{\rho}},$$

where $D(s^t)$ is the output of final goods and $y^d(h,i,s^t)$ and $y^d(f,i,s^t)$ are inputs of intermediate goods purchased from home firm i and foreign firm i, respectively. The parameters a_1 and a_2 determine the weight of home goods in final good consumption. The elasticity of substitution between intermediate goods that are produced in the same country is $1/(1-\theta)$, and the elasticity of substitution between home and foreign aggregate inputs is $1/(1-\rho)$.

The final goods market is competitive. In each period t, given the final good price at home $P(s^t)$, the i_{th} home intermediate good price at home $P(h,i,s^t)$ for $i \in [0,1]$, and the i_{th} foreign intermediate good price at home $P(f,i,s^t)$ for $i \in \mathcal{E}^*(s^t)$, a home final good producer chooses inputs $y^d(h,i,s^t)$ for $i \in [0,1]$, and $y^d(f,i,s^t)$ for $i \in \mathcal{E}^*(s^t)$ to maximize profits,

$$(4) \quad \max P\left(s^t\right) D\left(s^t\right) - \int_0^1 P\left(h,i,s^t\right) y^d\left(h,i,s^t\right) di - \int_0^1 P\left(f,i,s^t\right) y^d\left(f,i,s^t\right) di,$$

subject to the production technology (3) and the constraint that $y^d\left(f,i,s^t\right) = 0$ for $i \notin \mathcal{E}^*(s^t)$.

[8] In the simulation exercises, κ is normalized to be 1.

Solving the problem in (4) gives the input demand functions,

$$(5) \qquad y^d(h,i,s^t) = a_1^{\frac{1}{1-\rho}} \left[\frac{P(h,i,s^t)}{P(h,s^t)}\right]^{\frac{1}{\theta-1}} \left[\frac{P(h,s^t)}{P(s^t)}\right]^{\frac{1}{\rho-1}} D(s^t),$$

$$(6) \qquad y^d(f,i,s^t) = a_2^{\frac{1}{1-\rho}} \left[\frac{P(f,i,s^t)}{P(f,s^t)}\right]^{\frac{1}{\theta-1}} \left[\frac{P(f,s^t)}{P(s^t)}\right]^{\frac{1}{\rho-1}} D(s^t), i \in \mathcal{E}^*(s^t)$$

where $P(h,s^t) = \left[\int_0^1 P(h,i,s^t)^{\frac{\theta}{\theta-1}} di\right]^{\frac{\theta-1}{\theta}}$, and $P(f,s^t) = \left[\int_{i\in\mathcal{E}^*(s^t)} P(f,i,s^t)^{\frac{\theta}{\theta-1}} di\right]^{\frac{\theta-1}{\theta}}$. The zero-profit condition in the perfectly competitive market determines the price level of the final good and is

$$P(s^t) = \left[a_1^{\frac{1}{1-\rho}} P(h,s^t)^{\frac{\rho}{\rho-1}} + a_2^{\frac{1}{1-\rho}} P(f,s^t)^{\frac{\rho}{\rho-1}}\right]^{\frac{\rho-1}{\rho}}.$$

C. International Trading Costs

An intermediate good producer can sell its product without frictions in the domestic market. It is costly, however, to sell its product abroad. Producers that export to the foreign country face two sets of international trading costs. To enter the foreign market, an intermediate good producer has to pay a (relatively) high initial entry costs τ_0. From the following period on, to continue exporting the producer has to pay a lower but nonzero continuation costs τ_1 ($< \tau_0$). The export penetration costs (τ_0) and continuation costs (τ_1) are collected from foreign exporting firms by the domestic government, and distributed lump-sum to the domestic consumers. The government's budget constraint is given by

$$(7) \quad T(s^t) = \int_{i\in\mathcal{E}^*(s^t)} \left\{[1 - m^*(i,s^{t-1})]\tau_0 + m^*(i,s^{t-1})\tau_1\right\} di,$$

where $m^*(i,s^t)$ is an indicator function denoting the export status of the i_{th} intermediate good producer in s^t. Let $m^*(i,s^t) = 1$ if the i_{th} foreign intermediate good producer is an exporter in s^t, 0 otherwise.[9] These trade costs imply that only a fraction

$$N^*(s^t) = \int_0^1 m^*(i,s^t) di$$

[9] In reality, most of the costs are paid to agents that help exporting firms, not to the foreign government. However, no matter to whom the costs are paid initially, the payment goes to consumers ultimately. Additionally, in practice some of these costs are also paid to domestic agents. The results of the simulation exercises are not sensitive to the division of these costs across countries. To make matters simple, it is assumed that the costs are paid to the foreign government.

of foreign intermediate goods are available to home final good producers in state s^t.

D. Intermediate Goods Producers

In each country there is a large number of intermediate good producers normalized to a continuum with unit mass indexed $i \in [0,1]$ who behave as monopolistic competitors. An intermediate good firm produces its differentiated good with a Cobb-Douglas production technology,

$$F(i,s^t) = A(i,s^t)k(i,s^{t-1})^{\alpha}l(i,s^t)^{1-\alpha} = y^d(h,i,s^t) + y^{*d}(h,i,s^t), \tag{8}$$

where $y(h,i,s^t)$ and $y^*(h,i,s^t)$ are the amounts of good i sold in the home and foreign intermediate goods markets, respectively and $k(i,s^{t-1})$ and $l(i,s^t)$ are the capital and labor inputs of the firm i. Capital used in production is augmented by investment of final goods, $x(i,s^t)$. The law of motion for capital is given by

$$k(i,s^t) = (1-\delta)k(i,s^{t-1}) + x(i,s^t), \tag{9}$$

where δ is the depreciation rate.

The term $A(i,s^t)$ denotes the productivity of the i_{th} firm and is composed of a country-wide component $z(s^t)$, and a firm-specific component $\eta(i,s^t)$ such that

$$\ln A(i,s^t) = z(s^t) + \eta(i,s^t).$$

The country-wide component $z(s^t)$ may be correlated across countries and evolves according to a vector autoregressive process (VAR) with the foreign country-wide productivity, $z^*(s^t)$,

$$Z(s^t) = MZ(s^{t-1}) + \nu(s^t), \nu(s^t) \overset{iid}{\sim} N(0,\Omega),$$

where M is a coefficient matrix; $Z(s^t) = [z(s^t), z^*(s^t)]'$ and $\nu(s^t) = [\epsilon(s^t), \epsilon^*(s^t)]'$. The firm-specific productivity is independently, identically distributed across countries, firms, and time, $\eta(i,s^t) \overset{iid}{\sim} N(0,\sigma_\eta^2)$.

Consider the problem of an intermediate good producer from the home country in state s^t. The state of an individual firm is completely expressed by the triple (η, k, m), where we temporarily drop the firm index and state in a slight abuse of notation. The intermediate good producer chooses current prices P, P^*, inputs of labor l, investment x and the export decision m' to solve

$$V\left(\eta, k, m, s^t\right) = \max \Pi(h, i; s^t) + m_t \Pi^*(h, i; s^t) + \sum_{s^{t+1}} \sum_{\eta'} Q\left(s^{t+1}|s^t\right) \Pr\left(\eta'\right) V\left(\eta', k', m', s^{t+1}\right),$$

$$\Pi(h, i; s^t) = P(h, i, s^t) y(h, i, s^t) - P(s^t) w(s^t) l(i, s^t) - P(s^t) x(i, s^t)$$

$$\Pi^*(h, i, s^t) = e(s^t)\left[P^*(h, i, s^t) y^*(h, i, s^t) - P^*(s^t)[m\tau_1 + (1-m)\tau_0]\right],$$

subject to the production technology (8), the law of motion for capital (9), and the constraints that supplies to home and foreign intermediate goods market $y(h, i, s^t)$ and $y^*(h, i, s^t)$ are equal to demands by home and foreign final good producers $y^d(h, i, s^t)$ and $y^{d*}(h, i, s^t)$ from (5) and its foreign analogue. Here, $\Pr(\eta')$ denotes the probability of an idiosyncratic shock η'. $Q(s^t)$ is the price of one unit of home currency in s^t in an abstract unit of account. Since firms are owned by domestic consumers, $Q(s^{t+1})/Q(s^t)$ should be the same as the intertemporal marginal rate of substitution. From the bond price condition (1), $Q(s^{t+1})/Q(s^t) = Q(s^{t+1}|s^t)$.

Let the value of the i_{th} producer if it exports in s^t be

$$V^1\left(\eta, k, m, s^t\right) = \max \Pi(h, i; s^t) + \Pi^*(h, i; s^t) + \sum_{s^{t+1}} \sum_{\eta'} Q\left(s^{t+1}|s^t\right) \Pr\left(\eta'\right) V\left(\eta', k', 1, s^{t+1}\right),$$

$$\Pi(h, i; s^t) = P(h, i, s^t) y(h, i, s^t) - P(s^t) w(s^t) l(i, s^t) - P(s^t) x(i, s^t)$$

$$\Pi^*(h, i, s^t) = e(s^t) P^*(h, i, s^t) y^*(h, i, s^t) - e(s^t) P^*(s^t)[m\tau_1 + (1-m)\tau_0],$$

and the value of the i_{th} producer if it does not export in s^t be

$$V^0\left(\eta, k, m, s^t\right) = \max \Pi(h, i; s^t) + \sum_{s^{t+1}} \sum_{\eta'} Q\left(s^{t+1}|s^t\right) \Pr\left(\eta'\right) V\left(\eta', k', 0, s^{t+1}\right),$$

$$\Pi(h, i; s^t) = P(h, i, s^t) y(h, i, s^t) - P(s^t) w(s^t) l(i, s^t) - P(s^t) x(i, s^t)$$

Then, the actual value of i_{th} producer can be defined as

$$V\left(\eta, k, m, s^t\right) = \max\left\{V^1\left(\eta, k, m, s^t\right), V^0\left(\eta, k, m, s^t\right)\right\}.$$

Clearly the value of a producer depends on its export status and are monotonically increasing and continuous in η, and V^1 intersects V^0 from below only once.[10] Hence, it is possible to solve for the

[10] If the difference between τ_0 and τ_1 is very large, $V^1 > V^0$ for all $\eta \in (-\infty, \infty)$ for some s^t. Since the data show

firm-specific productivity at which a firm is indifferent between exporting or not exporting. This level of technology differs by the firms current export status. The critical level of technology for exporters and non-exporters, η_1 and η_0, satisfy

$$(10) \quad V^1\left(\eta_1, k, 1, s^t\right) = V^0\left(\eta_1, k, 1, s^t\right),$$

$$(11) \quad V^1\left(\eta_0, k, 0, s^t\right) = V^0\left(\eta_0, k, 0, s^t\right),$$

In general these critical technology levels will differ across firms based on their capital level. However, the assumption that firm specific technology shocks are iid implies that each firm expects to draw the same level of technology tomorrow. Consequently, a firm's current capital stock is entirely determined by its export status in the previous period. As export status is a zero-one choice, the distribution of capital over firms is characterized by two mass points. This then implies that the critical technology level of an exporting firm also determines the technology of the marginal exporting firm, which we denote by $\eta_1\left(s^t\right)$. Among last period exporters, only those with a firm-specific productivity greater than $\eta_1(s^t)$ will continue to export in state s^t. Likewise, the critical technology of a non-exporter is denoted by $\eta_0\left(s^t\right)$.

From (10), (11), and the independence of the firm-specific productivity, the percentage of exporters in s^t among exporters and non-exporters in s^{t-1}, $n_1(s^t)$ and $n_0(s^t)$, respectively, can be defined as

$$n_1(s^t) = \Pr[\eta > \eta_1(s^t)],$$

$$n_0(s^t) = \Pr[\eta > \eta_0(s^t)].$$

Then, the law of motion for the export ratio among intermediate good producers, $N(s^t)$, is

$$(12) \quad N(s^t) = n_1(s^t)N(s^{t-1}) + n_0(s^t)[1 - N(s^{t-1})].$$

Figure 1 illustrates the values of firms across firm-specific productivity depending on export status. In the absence of trade costs, the value of a firm that exports always exceeds the value of not exporting for all firm-specific productivity. This is true because by exporting the firm has a larger market for its goods so that without the fixed costs all firms export their good abroad.

that some of the previous exporters exit from foreign markets each period, it is assumed through out that the shocks are small enough that this does not occur.

However, in the presence of international trade costs, it is not optimal for some firms to export goods abroad. The value of an exporting firms is reduced by the amount of the trade costs, τ_0 or τ_1 depending on the export status last period. Since the cost of being a new exporter exceeds the cost of continuing to export, $\tau_0 > \tau_1$, the value of being a new exporter is always lower than the value of being a continuing exporter. This implies that $\eta_1(s^t) < \eta_0(s^t)$ for all s^t. Hence, the probability of being an exporter in s^t is always higher for last period exporters than last period non-exporters ($n_1(s^t) > n_0(s^t)$).

E. Equilibrium Definition

In an equilibrium, variables satisfy several resource constraints. The final goods market clearing conditions are given by $c(s^t) + \int x(i, s^t)di = D(s^t)$, and $c^*(s^t) + \int x^*(i, s^t)di = D^*(s^t)$. The intermediate goods market clearing conditions are $y^d(h, i, s^t) = y(h, i, s^t)$ for $i \in [0, 1]$, $y^d(f, i, s^t) = y(f, i, s^t)$ for $i \in \mathcal{E}^*(s^t)$, $y^{d*}(f, i, s^t) = y^*(f, i, s^t)$ for $i \in [0, 1]$, and $y^{d*}(h, i, s^t) = y^*(h, i, s^t)$ for $i \in \mathcal{E}(s^t)$. The labor market clearing conditions are $l(s^t) = \int_0^1 l(i, s^t)di$, and $L^*(s^t) = \int_0^1 L^*(i, s^t)di$. The profits of firms are distributed to the shareholders, $\Pi(s^t) = \int_0^1 \Pi(h, i, s^t) + \Pi^*(h, i, s^t)di$, and $\Pi^*(s^t) = \int_0^1 \Pi(f, i, s^t) + \Pi^*(f, i, s^t)di$. The government budget constraint is given by (7) and the foreign analogue. The international bond market clearing condition is given by $B(s^t) + B^*(s^t) = 0$. Finally, our decision to write the budget constraints in each country in units of the local currency permits us to normalize the price of consumption in each country as $P(s^t) = P^*(s^t) = 1$.

An equilibrium of the economy is a collection of allocations for home consumers $c(s^t)$, $l(s^t)$, $B(s^{t+1})$; allocations for foreign consumers $c^*(s^t)$, $l^*(s^t)$, $B^*(s^{t+1})$; allocations for home final goods producers $D(s^t)$, $y^d(h, i, s^t)$ for $i \in [0, 1]$, and $y^d(f, i, s^t)$ for $i \in \mathcal{E}^*(s^t)$; allocations for foreign final good producers $D^*(s^t)$, $y^{d*}(f, i, s^t)$ for $i \in [0, 1]$, and $y^{d*}(h, i, s^t)$ for $i \in \mathcal{E}(s^t)$; allocations and prices for home intermediate good producers $l(i, s^t)$, $x(i, s^t)$, $y(h, i, s^t)$, and $P(h, i, s^t)$ for $i \in [0, 1]$, $y^*(h, i, s^t)$ and $P^*(h, i, s^t)$ for $i \in \mathcal{E}(s^t)$; allocations and prices for foreign intermediate good producers $l^*(i, s^t)$, $x^*(i, s^t)$, $y(f, i, s^t)$ and $P(f, i, s^t)$ for $i \in \mathcal{E}^*(s^t)$, $y^*(f, i, s^t)$ and $P^*(f, i, s^t)$ for $i \in [0, 1]$; the export statuses of home and foreign intermediate good producers $m(i, s^t)$ and $m^*(i, s^t)$ for $i \in [0, 1]$; transfers $T\left(s^t\right), T^*\left(s^t\right)$ by home and foreign governments; real wages $w(s^t), w^*(s^t)$, real and nominal exchange rates $q\left(s^t\right)$ and $e\left(s^t\right)$; and bond prices $Q(s^{t+1}|s^t)$ that satisfy the following conditions: (i) the consumer allocations solve the consumer's problem; (ii) the final good producers' allocations solve their profit maximization problems; (iii) the intermediate good producers' allocations, prices, and export statuses solve their profit maximization problems; (iv) the market clearing conditions hold; and (v) the transfers satisfy the government budget constraint.

In what follows we concentrate on a stationary equilibrium. A stationary equilibrium consists of stationary decision rules and pricing rules that are functions of the state of the economy. The state of the economy is completely described by the distribution of the state variables (η, k, m) for all individual firms in both countries and the aggregate technology shocks. The state of the economy when firms make their export decisions must record the joint distribution of the capital stock, technology and export status of firms in both countries. In general, keeping track of this distribution over time is computationally difficult. However, the assumption that firm specific technology shocks are iid greatly simplifies the analysis as it implies that last period's export status is sufficient to determine a firm's current capital stock. As firms are either exporters or non-exporters, at any point in time firms will have either a relatively low capital stock if they did not export yesterday or a relatively high capital stock if they did export yesterday. Consequently, the distribution of the capital stock in the economy is completely summarized by the aggregate shocks, Z and Z^*,the capital stock of exporters, K_1 and K_1^*, the capital stock of non-exporters, K_0 and K_0^*, and the share of exporters in each country, N and N^*.

F. Calibration

We now describe the functional forms and parameters values considered for our benchmark economy. The parameter values used in the simulation exercises are reported in Table 2. The instantaneous utility function is given as

$$U(c, l) = \frac{[c^{\gamma}(1-l)^{1-\gamma}]^{1-\sigma}}{1-\sigma},$$

where $1/\sigma$ is the inter-temporal elasticity of substitution, and γ is the share parameter for consumption in the composite commodity.

In the steady state, the real interest rate is equal to $(1-\beta)/\beta$. The annual real return to capital is around 4%. This gives $\beta = 0.99$. The steady state constraint gives $Y = C + \delta K$. Dividing both sides by K, $\delta = \frac{Y}{K}\left(1 - \frac{C}{Y}\right)$. With the annual capital output ratio of 2.5 and consumption to output ratio of 0.75 as the average of the post-war U.S. data, $\delta = 0.025$. The curvature parameter, σ, determines the inter-temporal elasticity of substitution and the relative risk aversion of consumers. Empirical studies using the U.S. time series, such as that of Eichenbaum et al. (1988), suggest that σ lies between 0.5 and 3. We consider a value of $\sigma = 2$ as this is widely used in the international business cycle literature, e.g., Backus et al. (1992), Stockman and Tesar (1995), Kollman (1997), and Kehoe and Perri (2002).

The parameter θ determines an intermediate good producer's markup. Schmitt-Grohe (1997) summarizes the results of empirical studies estimating this markup. These estimates vary widely from 3% to 70%. Based on Basu and Fernald (1994), θ is set to be equal to 0.9 and yields an intermediate good producer's markup of about 11%. The parameter ρ determines the elasticity of substitution between home and foreign aggregates, $1/(1-\rho)$. There is considerable disagreement over an appropriate value. Using the U.S. quarterly data of 163 industries at the 3-digit SIC level from 1980:1 to 1988:4, Gallaway, et al. (2000) estimate that the elasticities range from 0.14 to 3.49. Reinert and Roland-Holst (1992) estimate the elasticities using the U.S. monthly data of 309 industries at the 4-digit SIC level from 1989:1-1995:12. Their estimates range from 0.52 to 4.83. In the simulation exercises, ρ is set to 1/3 so that the elasticity equals to 1.5 as in Backus et al. (1992) and Chari et al. (2001).

In the model, the share of output that goes to labor is $\theta(1-\alpha)$. In the post-war U.S. data, the share is about 2/3. This implies $\alpha = 0.259$, given the parameter value $\theta = 0.9$. The share parameter for consumption in the composite commodity, γ, is set to be equal to 0.294. This value is obtained from the observation that the average time devoted to work is 1/4 of the total available time, and the consumption-output ratio is about 0.75 in the post-war period.

The parameters τ_0, τ_1, a_2 and σ_η jointly determine the amount of trade, characteristics of exporters and non exporters, and the dynamics of export status.[11] To pin these parameters down, we consider the following evidence (a_1 is normalized to 1). First, as in Table 1, using annual data Bernard and Jensen (1999) find that about 87.8 percent of exporters continue exporting in the next period, and among those that did not export last period, about 85.6 percent of firms remain in the non-exporter status. Consequently, we set $n_1 = n_0 = 3.5\%$ to match an average of the quarterly starter and stopper ratios from Bernard and Jensen (1999). Second, Bernard and Jensen (1999) find that exporters are 12 percent to 18 percent more productive than non-exporters. Finally, we note that for the U.S., the import to output ratio is approximately 15%. Choosing these parameters

[11] An alternate approach is to calibrating the firm shocks is to use previous estimate for the firm-specific productivity process. However, these studies tend to rely heavily on the sample of firms. With very small firms in the sample, the variance becomes very large. With only large firms, such as firms that can be found in S&P 500, the size of the variance becomes very small. Bernard, et al. (2003) estimate the distribution across plants of value added per workers using ASM 1992. They find that the sample standard deviation of the productivity across firms is about 0.76. However, their estimate differs due to the differences in production functions and the processes of technology shocks. For the robustness of the simulation results, various values of the standard deviation for the firm-specific productivity are considered.

jointly, to match these statistics yields values of $\tau_0 = 0.087, \tau_1 = 0.022, a_2 = 0.322$ and $\sigma_\eta = 0.4$.[12] The choice of $\sigma_\eta = 0.4$ is made as it leads exporters to be 12.4% more productive and to ship 93.2% more output (and hire 93.2% more workers). The characteristics of exporters in terms of employment, and output matches up well with the data as exporters produce 104 to 115 percent more output than non-exporters and hire 77 percent to 95 percent more workers. With these parameter values, on average, a new exporter pays about 9.6% of exports as entry costs, and a continuing export pays about 0.3% of exports to remain in the foreign market in the steady state.

There are several sets of parameters values for the country specific productivity process that are used in the literature. The benchmark model follows the parameter values in Kehoe and Perri (2002)

$$\mathbf{M} = \begin{bmatrix} .95 & 0 \\ 0 & .95 \end{bmatrix}$$

with $Var[\epsilon(s^t)] = Var[\epsilon^*(s^t)] = \sigma_\epsilon^2 = 0.007^2$, and $Corr[\epsilon(s^t), \epsilon^*(s^t)] = 0.25$. In the sensitivity analyses, the model with a 'spillover' effect as in Backus, et al (1992) is also simulated.

The model is simulated for 1000 times with 100 periods using the linearization methods suggested by King, et al. (1988a,b), and Klein (2000).

4. Findings

We report the H-P filtered statistics for the data, the benchmark economy, and some variations on that economy in Table 3. As a baseline, to evaluate the role of export characteristics and dynamics for the propagation of international business cycles, we compare the results from the model with the export penetration and continuation costs to a model without the costs, denoted no costs. The no cost model is essentially a version of the Backus et al. (1994) with heterogenous monopolistically competitive firms. The sensitivity analyses are also performed in the simulation exercises.

A. Benchmark Model

We find that the benchmark model generates commovements in business cycles across countries that closely match the data. In particular, exporter dynamics appear to offer a possible resolution to the consumption correlations and international comovement puzzles. In Table 3, we

[12] Under the zero export penetration costs, $\tau_0 = \tau_1 = 0$, a_2 set to be equal to 0.315 to match the exports to output ratio of 0.15.

see that in the benchmark model output is more positively correlated across countries than consumption (0.43 vs. 0.20). We also see that the international correlation of investment (0.39) and employment (0.64) are positive and closely match the data. Compared to a model with no costs, these export costs generate considerably more comovement in economic activity across countries and lower the comovement of consumption.

B. Impulse Response

To compare how the mechanisms for international transmissions of business cycles differ between models with and without export penetration costs, the responses of variables to a positive one standard deviation home country-wide productivity shock are plotted in Figure 2. Figure 2H depicts the responses of the turnover ratios in export status.

When there is a positive country-wide productivity shock at home, home intermediate good producers experience a reduction in their costs of production. Hence, an increased number of producers transition from non-exporter to exporter status, and fewer producers transition from exporter to non-exporter status. The big change in export dynamics works through a decrease in the fraction of exporters stopping to export. This results in a gradual increase in the measure of home exporters, which peaks about 12 quarters after the initial shock.

The foreign intermediate good producers' experience is different. Even though foreign producers experience unchanged country-wide productivity, they experience a persistent increase in home country's demand for their goods. The increase in demand raises the value of a foreign producer exporting and generates an increase in the measure of foreign exporters. Hence, a larger number of non-exporters start exporting and fewer exporters stop exporting. These movements result in an increase in the measure of foreign exporters, which peaks about 4 quarters after the initial shock.

The growth in the foreign export sector is primarily accomplished through a reduction in the exit margin. This is to be expected as current exporters face substantially smaller current costs of staying in the market than non-exporters face to enter the market, and the value of being an exporter depends strongly on the future sustained investment and consumption boom at home. Consequently, those current exporters with relatively low technology shocks find it profitable to pay the continuation cost and defer exit to export to the home country.

To understand the consumption correlation across countries it is useful to think in terms of the risk sharing and the dynamics of capital accumulation in the model. An increase in home productivity leads to an increase in investment. This is immediate and is accomplished in part by more foreign varieties, which reduce the cost of producing the final home good. Because of the strong incentive to accumulate capital in the home country immediately following the shock, it is worthwhile to ship large quantities of the foreign varieties in the first few periods after the shock. Consequently, foreign exporters initially increase employment and then build their capital stock. This mechanism leads employment and investment levels to increase both at home and foreign (Figure 2 C and D) following the shock. Output levels in both countries also rise with the increases in inputs (Figure 2 A). Over time, as the capital stock in home increases, this augments the productivity shock to lower the production cost of home exporters. This leads to less exit of home exporters and builds up the variety of home intermediates in the foreign country. These additional varieties of home exports reduce the cost of the composite consumption good. Hence, consumption at home increases from the initial period of the shock, whereas consumption at foreign decreases initially (Figure 2 B). From the second period on, consumption in both countries follow a qualitatively similar path. However, these opposite movements on impact imply that the consumption correlation across countries is lower than the output correlation across countries.

5. Sensitivity Analysis

This section discusses simulation results under various model modifications. We consider our benchmark model modified to include changes in the volatility of the firm-specific productivity, persistence of export status, incomplete asset markets, separable preferences and a different process for country specific shocks. We also discuss the role of introducing exogenously determined non-traded and traded goods as in Stockman and Tesar (1995).

A. Volatility of firm specific shock

Figure 3 depicts the sensitivity of the model to the volatility of the firm specific shocks, $\sigma_\eta \in [0.05, 0.60]$.[13] For each σ_η,we recalibrate the export penetration and continuation costs so that the starter and stopper ratios are constant. With higher σ_η this requires increasing the export penetration costs and decreasing the continuation cost. These changes imply that the productivity and size of the average exporter is increasing in σ_η.

For $\sigma_\eta \in [0.05, 0.40]$ the cross-country correlations are quite stable. Output correlations range from 0.43 to 0.50, consumption correlations from 0.20 to 0.24, investment correlations from 0.24 to

[13] Bernard et al (2002) estimate the distribution across plants of value added per workers using the U.S. Annual Survey of Manufactures 1992. They find that the standard deviation of productivity across firms is about 0.76.

0.42, and employment correlations from 0.55 to 0.64. For higher σ_η,the cross-country correlations of output, investment, and employment increase substantially while the cross-country correlations in consumption decrease. Over the entire range, the results show that the consumption correlations are always lower than the output correlations, and all the correlations, output, consumption, investment, and employment, are positive. Hence, with plausible values for σ_η, the model generates positive cross-country correlations in output, consumption, investment, and employment, and the consumption correlations that lies below the output correlations.

B. Persistence of Export Status

Table 4 documents how the propogation of business cycles varies with changes in the persistence of export status. We compare the baseline model to one with low in which 75 percent of the firms exporting today continue to export in a year and model with high persistence in which 94 percent of today's exporters continue to export in a year. In both cases, we maintain an exporter ratio of 50 percent. To increase the persistence of exporter status requires raising the ratio of entry cost to continuation cost, τ_0/τ_1. This increases the cutoff for the idiosyncratic shock to enter the export market, η_0, and decreases the cutoff for the idiosyncratic shock to exit the export market, η_1. For the range of persistence considerered, lowering the persistence of export status increases comovements in economic activity and lowers comovements in consumption.

C. Incomplete Asset Markets

In the benchmark model, it is assumed that home and foreign consumers can buy or sell a complete menu of state contingent bonds. In this section, we modify the model so that only one period non-state contingent risk-free bonds issued by home consumers are available. The budget constraint for home consumers with the bond becomes

$$P(s^t)C(s^t) + \overline{Q}(s^t)\overline{B}(s^t) \leq P(s^t)W(s^t)L(s^t) + \overline{B}(s^{t-1}) + \Pi(s^t) + P(s^t)T(s^t),$$

where $\overline{Q}(s^t)$ is the nominal price of the uncontingent risk-free bond $\overline{B}(s^t)$ at period t. $\overline{B}(s^t)$ is the amount of the bonds that the consumer buys at period t. The bond $\overline{B}(s^t)$ pays 1 unit of home currency at period $t+1$ regardless of the state at period $t+1$. Under this constraint, the equation for the real exchange rate (2) changes to

$$\sum_{s^{t+1}} \pi(s^{t+1}|s^t)\frac{U_c(s^{t+1})P(s^t)}{U_c(s^t)P(s^{t+1})} = \sum_{s^{t+1}} \pi(s^{t+1}|s^t)\frac{U_C^*(s^{t+1})q(s^t)P(s^t)}{U_C^*(s^t)q(s^{t+1})P(s^{t+1})}.$$

The results with the modified model are in Table 5.[14] Without the trade costs, the incomplete asset market assumption lowers the consumption correlation across countries, and increases the employment correlation compared to the correlations under complete asset market condition. However, the modified model still generates the consumption correlation, 0.45, which is higher than the output correlation, 0.34, very low investment correlation, 0.05, and low employment correlation, 0.26.

With incomplete markets in the export penetration cost model there are no consumption correlation or international comovement puzzles. In fact, now comovements are too strong in inputs and there is not enough comovement in consumption. The international consumption correlation is actually negative, -0.07, which is lower than the data statistic, 0.32, and lower than the output correlation, 0.51. The investment correlation is 0.39 and the employment correlation 0.72.

D. Separable Preferences

We consider an alternative specification for preferences. Consider separable preferences defined as

$$U(C,L) = \frac{C^{1-\sigma}}{1-\sigma} + \psi \frac{(1-L)^{1-\gamma}}{1-\gamma}.$$

In the simulation $\psi = 2.433$, and $\sigma = \gamma = 2$ are used. The results are reported in Table 5 in the column titled Seperable.

The baseline model without export penetration costs exhibits the familiar consumption and international comovement puzzles. Now the correlation of consumption across countries is positive, large and substantially exceeds the correlation of output (0.68 vs. 0.10). Moreover, employment is negatively correlated across countries while the cross correlation of investment is positive but low.

With export penetration costs, the model comes closer to the data. In particular, the cross-country employment correlation is positive, 0.54, and so is the investment cross correlation, 0.25. However, the consumption correlation puzzle returns as the consumption correlation is 0.44 and the output correlation is 0.34. With seperable preferences, export penetration costs substantially reduce the discrepancy between theory and data.

[14] In the simulations a very small quadratic cost is imposed so that the law of motion for bonds is stationary.

E. Spillover

In Backus et al. (1992), it is assumed that the process for the country-wide productivity has spillover effects (non-zero values for off-diagonal terms in the coefficient matrix **M**). The results using their productivity process specification are reported in Table 5 in the column titled Spillover.[15]

Similarly to Backus et al. (1992), the modified model without export penetration costs predicts negative cross-country correlations in investment and employment, -0.63 and -0.58, respectively. The model also predicts higher consumption correlation than output correlation. The consumption correlation is 0.78, and the output correlation is 0.10.

The modified model with export penetration costs also fails to show correct signs for international correlations in investment and employment, although the costs make the correlations be closer to the data statistics. The investment and employment correlations are -0.33 and -0.06, respectively. The model also predicts higher cross-country consumption correlation, 0.64, than the output correlation, 0.19, even though the costs lowers the difference between these two correlations. Overall, the export penetration costs moves the basic model closer to the data, but there are still a large differences from the data.

F. Exogenous traded and non-traded goods

In this section, we compare the model to one in which firms are exogenously divided between being exporters and non-exporters. This exercise permits us to determine the role of exporter dynamics versus the role of introducing some non-traded goods into the model.

We keep the same structure as before in that firms differ in their technology. We make two changes to the baseline model. First, we assume that in each country firms $i \leq 0.5$ can only sell at home and firms with $i > 0.5$ can sell in both markets. This exogenously divides the market between traded and non-traded goods. Effectively, non-traded goods face infinite fixed costs of exporting while traded goods face no fixed costs of exporting. Second, we assume that the mean technology shock for exporters exceeds that for non exporters. The shock for firms is

$$\ln A(i, s^t) = \mu(i) + z(s^t) + \eta(i, s^t),$$

where $\mu(i) = 0$ for $i \in [0, 0.5]$ and$\mu(i) = \mu \geq 0$ otherwise. We introduce this technology difference

[15]For the process of the productivity, the modified model uses $M = \begin{bmatrix} 0.906 & 0.088 \\ 0.088 & 0.906 \end{bmatrix}$ with $\sigma_\epsilon^2 = 0.00852^2$, and $Corr[\epsilon(s^t), \epsilon^*(s^t)] = 0.258$.

across firms to match some of the features of exporters we have discussed.

The last two columns of table 3 describe the impact of two experiments. First, we consider calibrating the size of the export sector to the relative size of exporters. This requires a mean technology difference between average exporters and non-exporters of 4.3%. The results are reported in the column titled $A_x/A_n = 1.043$. In this case, investment across countries is uncorrelated and the consumption and output correlations are of equal magnitudes.

Our final experiment is to match the difference between average exporters and non-exporters of 12.4%. In this case, the model implies that exporters produce 225 percent more than non-exporters, which is much more than our endogenous exporters produce, which only produced about 93 percent more than non-exporters. This differences arises in part because the technology difference and participation are now permanent. The results of the model are reported in the column titled $A_x/A_n = 1.124$. Not surprisingly both puzzles reappear. As we increase the productivity of the exporting sector we are making the model more similar to the baseline model of Backus et al. (1994).

These findings suggest that just introducing some non-tradables contributes some to eliminating these puzzles. They also suggest that introducing exogenous differences in exporters and non-exporters weakens the role of non-tradabilty. We interpret this to imply that the endogenous choice to export influences international propagation in a different way than just introducing some non-tradable goods. Finally, with an endogenous export sector we are able to come close to matching the output and productivity premium of exporters. Thus, this churning in the export sector appears to matter for explaining characteristics of the firm size distribution as well as the propogation of business cycles.

6. Conclusions

In this paper we develop a model of trade driven by firms facing fixed costs of entering and participating in foreign markets to study the propagation of business cycles across countries. We find that a model calibrated to match certain characteristic of the export sector generates comovements in economic activity across countries that match the data. In particular, the model developed here offers a resolution of the consumption correlation and international comovement puzzles.

The mechanism described in the model suggests a particular pattern of export participation across countries and over the business cycle. To determine whether the channel explored here is important in practice requires more empirical work into how these export decisions vary over the business cycle.

The current model has a number of shortcomings. First, we have concentrated on a limited set of facts about exporters. In particular, we have focused on the differences between the average exporters and average non-exporters with little concern about the difference among firms within these sectors. Clearly, there are large differences between major exporters like GM, Ford, and Boeing and the rest of the export sector which may matter. Second, investment and net exports in the model are much too volatile compared to the data. Introducing capital adjustment costs into this framework will likely lower the volatility of these aggregates. Finally, we have focused on a number of puzzles in the movements of quantities across countries over time. There are a number of important features of fluctuations in prices that this model is not designed to address, but may matter for the export decisions of firms.

Appendix

Consumer's Problem: The first order conditions for the home consumer are:

$$-\frac{U_L(s^t)}{U_C(s^t)} = W(s^t), \tag{13}$$

$$Q(s^{t+1}|s^t) = \beta Pr(s^{t+1}|s^t)\frac{U_C(s^{t+1})P(s^t)}{U_C(s^t)P(s^{t+1})}. \tag{14}$$

Similarly, the first order conditions for the foreign consumer are:

$$-\frac{U_L^*(s^t)}{U_C^*(s^t)} = W^*(s^t), \tag{15}$$

$$Q^*(s^{t+1}|s^t) = \beta Pr(s^{t+1}|s^t)\frac{U_C^*(s^{t+1})P^*(s^t)}{U_C^*(s^t)P^*(s^{t+1})}, \tag{16}$$

$$Q(s^{t+1}|s^t) = \beta Pr(s^{t+1}|s^t)\frac{U_C^*(s^{t+1})e(s^t)P^*(s^t)}{U_C^*(s^t)e(s^{t+1})P^*(s^{t+1})}. \tag{17}$$

From the state contingent bond equations (14) and (17), we get

$$\frac{U_C(s^{t+1})P(s^t)}{U_C(s^t)P(s^{t+1})} = \frac{U_C^*(s^{t+1})e(s^t)P^*(s^t)}{U_C^*(s^t)e(s^{t+1})P^*(s^{t+1})}. \tag{18}$$

The real exchange rate is defined as $q(s^t) = \frac{e(s^t)P^*(s^t)}{P(s^t)}$. Iterating on (18) yields

$$q(s^t) = \kappa\frac{U_C^*(s^t)}{U_C(s^t)}, \tag{19}$$

where $\kappa = q(s^0)U_C(s^0)/U_C^*(s^0)$. For the simulations κ is normalized to be 1.

Final Good Producer's Problem: The focs for the home final good producer give the input demand functions

$$y^d(h,i,s^t) = a_1^{\frac{1}{1-\rho}}\left[\frac{P(h,i,s^t)}{P(h,s^t)}\right]^{\frac{1}{\theta-1}}\left[\frac{P(h,s^t)}{P(s^t)}\right]^{\frac{1}{\rho-1}} D(s^t), \tag{20}$$

$$y^d(f,i,s^t) = a_2^{\frac{1}{1-\rho}}\left[\frac{P(f,i,s^t)}{P(f,s^t)}\right]^{\frac{1}{\theta-1}}\left[\frac{P(f,s^t)}{P(s^t)}\right]^{\frac{1}{\rho-1}} D(s^t), \tag{21}$$

where $P(h,s^t) = \left[\int_0^1 P(h,i,s^t)^{\frac{\theta}{\theta-1}}di\right]^{\frac{\theta-1}{\theta}}$, and $P(f,s^t) = \left[\int_{i\in\mathcal{E}^*(s^t)} P(f,i,s^t)^{\frac{\theta}{\theta-1}}di\right]^{\frac{\theta-1}{\theta}}$. The zero-profit condition in final goods implies that

$$P(s^t) = \left[a_1^{\frac{1}{1-\rho}}P(h,s^t)^{\frac{\rho}{\rho-1}} + a_2^{\frac{1}{1-\rho}}P(f,s^t)^{\frac{\rho}{\rho-1}}\right]^{\frac{\rho-1}{\rho}}. \tag{22}$$

The resource constraint for the final goods gives

$$D(s^t) = C(s^t) + I(s^t). \tag{23}$$

Intermediate Good Producer's Problem: The first order conditions for the i_{th} home intermediate good producer give

$$\frac{P(h,i,s^t)}{P(s^t)} = q(s^t)\frac{P^*(h,i,s^t)}{P^*(s^t)} = \frac{W(s^t)}{\theta F_L(i,s^t)}, \tag{24}$$

$$P(s^t) = \sum_{s^{t+1}} \sum_{\eta(i,s_i^{t+1})} \frac{Q(s^{t+1})}{Q(s^t)} Pr[\eta(i,s^{t+1})] \left\{ \left(\frac{\alpha}{1-\alpha}\right) \cdot \frac{P(s^{t+1})W(s^{t+1})L(i,s^{t+1})}{K(i,s^t)} + P(s^{t+1})(1-\delta) \right\}. \tag{25}$$

The marginal cost of production is equal to $W(s^t)/F_L(i,s^t)$ and prices are a constant mark-up over marginal cost. Since firms in a country are owned by domestic consumers, clearly $Q(s^{t+1})/Q(s^t) = Q(s^{t+1}|s^t)$.

The resource constraint is defined as for good $i \in [0,1]$

$$y(h,i,s^t) + m(i,s^t)y^*(h,i,s^t) = A(i,s^t)K(i,s^{t-1})^{\alpha}L(i,s^t)^{1-\alpha}. \tag{26}$$

From the demand functions for intermediate goods (20) and (21), and the price decisions (24), the labor demand function can be obtained from (26).

$$L(i,s^t) = \left[\frac{W(s^t)}{\theta(1-\alpha)}\right]^{\frac{\nu}{\theta-1}} A(i,s^t)^{\frac{1-\nu}{\alpha}} K(i,s^{t-1})^{1-\nu} \left\{ \left[\frac{P(h,s^t)}{P(s^t)}\right]^{\mu} D_t + m(i,s^t) a_2^{\frac{1}{1-\rho}} q(s^t)^{\frac{1}{1-\theta}} \left[\frac{P^*(h,s^t)}{P^*(s^t)}\right]^{\mu} D_t^* \right\}^{\nu}, \tag{27}$$

where $\nu = \frac{\theta-1}{1-\theta(1-\alpha)}$, and $\mu = \frac{1}{1-\theta} - \frac{1}{1-\rho}$. Since $\eta(i,s^t)$ follows an *iid.* normal distribution, equation (25) implies that $K(i,s^t)$ is independent of $\eta(i,s^t)$ but depends on the firm's export status, $m(i,s^t)$, and the state of the world, s^t.

$$K(i,s^t) = \begin{cases} K_0(s^t) & \text{if } m(i,s^t) = 0, \\ K_1(s^t) & \text{if } m(i,s^t) = 1. \end{cases} \tag{28}$$

Hence, the sufficient statistics for the distribution of the capital among home intermediate good producers are $K_0(s^t)$, $K_1(s^t)$, and $N(s^t)$.

Marginal Exporters: Let $L_{m,m'}(i,s^t)$ and $I_{m,m'}(i,s^t)$ be the potentially sub-optimal levels of labor inputs and investment for the i_{th} firm when $m(i,s^{t-1}) = m$ and $m(i,s^t) = m'$, respectively. Clearly $I_{m,m'}(i,s^t) = I_{m,m'}(s^t) = K_{m'}(s^t) - (1-\delta)K_m(s^t)$. The problem of firm i with state (η,k,m) in aggregate state s^t is to solve the following problem

$$V\left(i,\eta,k,m;s^t\right) = \max\left\{V^0\left(i,\eta,k,m;s^t\right), V^1\left(i,\eta,k,m;s^t\right)\right\}$$

where V^0 is the maximal value of not exporting in the current period and V^1 is equal to the maximal value of exporting this period. From the mark-up pricing (24), the value of the i_{th} firm can be rewritten as

$$V^{m'}\left(\eta,k,m,s^t\right) = \left[\frac{1-\theta(1-\alpha)}{\theta(1-\alpha)}\right] P(s^t)W(s^t)L_{m,m'}(i,s^t) - P(s^t)I_{m,m'}(s^t) - m'e(s^t)P^*(s^t)\tau_m + \sum_{s^{t+1}} \sum_{\eta(i,s^{t+1})} Q(s^{t+1}|s^t)V\left(\eta',k',m',s^{t+1}\right) \tag{29}$$

where m, $m' \in \{0,1\}$. The firm-specific productivity of marginal exporters among last period exporters and non-exporters, $\eta_1(s^t)$ and $\eta_0(s^t)$, satisfy

$$(30) \quad V^1\left(\eta_j(s^t), K_j(s^{t-1}), m; s^t\right) = V^0\left(\eta_j(s^t), K_j(s^{t-1}), m; s^t\right),$$

where $m, j = \{0,1\}$. Let $\zeta_j \in [0,1]$ denote the identity of the firm with a shock such that $\eta\left(\zeta_j, s^t\right) = \eta_j\left(s^t\right)$, then the marginal exporter conditions (30) can be rewritten as

$$\begin{aligned} 0 \quad = (31) & \left[\frac{1-\theta(1-\alpha)}{\theta(1-\alpha)}\right] P(s^t)W(s^t)\left[L_{m,1}(\zeta_j, s^t) - L_{m,0}(\zeta_j, s^t)\right] - P(s^t)[K_1(s^t) - K_0(s^t)] \\ & -e(s^t)P^*(s^t)\tau_m + + \sum_{s^{t+1}} \sum_{\eta(\zeta_j, s^{t+1})} Q(s^{t+1}|s^t)\left(V\left[\eta\prime, K_1(s^t), 1; s^{t+1}\right] - V\left[\eta\prime, K_0(s^t), 0; , s^{t+1}\right]\right) \end{aligned}$$

$$\begin{aligned} L_{m,m'}(i, s^t) &= \left[\frac{W(s^t)}{\theta(1-\alpha)}\right]^{\frac{\nu}{\theta-1}} e^{\frac{1-\nu}{\alpha}[z(s^t)+\eta(i,s^t)]} K_m(s^{t-1})^{1-\nu} \\ (32) \qquad & \cdot\left[\left(\frac{P(h,s^t)}{P(s^t)}\right)^{\mu} D_t + m' a_2^{\frac{1}{1-\rho}} q(s^t)^{\frac{1}{1-\theta}}\left(\frac{P^*(h,s^t)}{P^*(s^t)}\right)^{\mu} D_t^*\right]^{\nu}. \end{aligned}$$

Among last period exporters, if the firm-specific productivity $\eta(i, s^t)$ is greater (less) than $\eta_1(s^t)$, the producer will (will not) export goods abroad in s^t. Among last period non-exporters, if the firm-specific productivity $\eta(j, s^t)$ is greater (less) than $\eta_0(s^t)$, the producer will (not) export goods abroad in s^t. Thus, the percentage of exporters in s^t among non-exporters and exporters in s^{t-1}, $n_0(s^t)$ and $n_1(s^t)$, respectively, can be defined as

$$(33) \quad n_m(s^t) = 1 - \Phi[\eta_m(s^t)],$$

where $m = \{0,1\}$. $\Phi(\eta)$ is the *cdf*. of $\eta(i, s^t)$. $N(s^t)$ is the percentage of exporters in s^t among all intermediate good producers. $N(s^t)$, evolves as

$$(34) \quad N(s^t) = n_1(s^t)N(s^{t-1}) + n_0(s^t)[1 - N(s^{t-1})].$$

Aggregate Variables

Capital and Investment: The aggregate capital at home in s^t is defined as

$$\begin{aligned} K(s^t) &= \int_{i\in\mathcal{E}(s^t)} K_1(s^t)di + \int_{i\notin\mathcal{E}(s^t)} K_0(s^t)di \\ (35) \qquad &= [1 - N(s^t)]K_0(s^t) + N(s^t)K_1(s^t). \end{aligned}$$

The aggregate investment at home in s^t is defined as

$$(36) \quad I(s^t) = K(s^t) - (1-\delta)K(s^{t-1}).$$

Labor Demand: The average labor demands in s^t from last period non-exporters and exporters, $L_0(s^t)$ and $L_1(s^t)$, can be defined as

$$L_0(s^t) = \frac{\int_{i\notin\mathcal{E}(s^{t-1})} L(i, s^t)di}{1 - N(s^{t-1})}, L_1(s^t) = \frac{\int_{i\in\mathcal{E}(s^{t-1})} L(i, s^t)di}{N(s^{t-1})}.$$

As η is iid from (32)

$$
\begin{aligned}
L_m(s^t) \quad &= \quad \left[\frac{W(s^t)}{\theta(1-\alpha)}\right]^{\frac{\nu}{\theta-1}} e^{\frac{1-\nu}{\alpha}z(s^t)} K_m(s^{t-1})^{1-\nu} \left\{ \left[\left(\frac{P(h,s^t)}{P(s^t)}\right)^{\mu} D_t \right]^{\nu} \right. \\
&\cdot \int_{-\infty}^{\eta_m(s^t)} e^{\frac{1-\nu}{\alpha}\eta}\phi(\eta)d\eta + \left[\left(\frac{P(h,s^t)}{P(s^t)}\right)^{\mu} D_t + a_2^{\frac{1}{1-\rho}} q(s^t)^{\frac{1}{1-\theta}} \right. \\
&\left. \left. \cdot \left(\frac{P^*(h,s^t)}{P^*(s^t)}\right)^{\mu} D_t^* \right]^{\nu} \int_{\eta_m(s^t)}^{\infty} e^{\left(\frac{1-\nu}{\alpha}\right)\eta}\phi(\eta)d\eta \right\}, \qquad (37)
\end{aligned}
$$

where m ={0,1}. $\phi(\eta)$ is the *pdf*. of η. The home aggregate labor demand is defined as

$$L(s^t) = [1 - N(s^{t-1})]L_0(s^t) + N(s^{t-1})L_1(s^t). \qquad (38)$$

Capital Decision Rules: The capital decision rules (25) as

$$1 = \sum_{s^{t+1}} Q(s^{t+1}|s^t)\frac{P(s^{t+1})}{P(s^t)} \left[\left(\frac{\alpha}{1-\alpha}\right) \frac{W(s^{t+1})L_m(s^{t+1})}{K_m(s^t)} + (1-\delta) \right]. \qquad (39)$$

Price Indices: From the mark-up pricing (24), and the labor demand function for the i_{th} firm, the price of the i_{th} firm can be rewritten as

$$
\begin{aligned}
\left[\frac{P(h,i,s^t)}{P(s^t)}\right]^{\frac{\theta}{\theta-1}} \quad &= \quad \left[\frac{W(s^t)}{\theta(1-\alpha)}\right]^{\frac{\nu+\theta-1}{\theta-1}} K_{m(i,s^{t-1})}^{1-\nu} e^{\left(\frac{1-\nu}{\alpha}\right)[z(s^t)+\eta(i,s^t)]} \left\{ \left[\frac{P(h,s^t)}{P(s^t)}\right]^{\mu} D(s^t) \right. \\
&\left. + m(i,s^t) a_2^{\frac{1}{1-\rho}} q(s^t)^{\frac{1}{1-\theta}} \left[\frac{P^*(h,s^t)}{P^*(s^t)}\right]^{\mu} D(s^t)^* \right\}^{\mu-1}, \qquad (40)
\end{aligned}
$$

$$\left[\frac{P^*(h,i,s^t)}{P^*(s^t)}\right]^{\frac{\theta}{\theta-1}} \quad = \quad q(s^t)^{\frac{\theta}{1-\theta}} \left[\frac{P(h,i,s^t)}{P(s^t)}\right]^{\frac{\theta}{\theta-1}}. \qquad (41)$$

Then, the aggregate export price $P^*(h,s^t)$ can be expressed as

$$
\begin{aligned}
\left[\frac{P^*(h,s^t)}{P^*(s^t)}\right]^{\frac{\theta}{\theta-1}} \quad &= \quad \left[\frac{W(s^t)}{\theta(1-\alpha)}\right]^{\frac{\nu+\theta-1}{\theta-1}} q(s^t)^{\frac{\theta}{1-\theta}} e^{\left(\frac{1-\nu}{\alpha}\right)z(s^t)} \left\{ \left[\frac{P(h,s^t)}{P(s^t)}\right]^{\mu} D(s^t) \right. \\
&\left. + a_2^{\frac{1}{1-\rho}} q(s^t)^{\frac{1}{1-\theta}} \left[\frac{P^*(h,s^t)}{P^*(s^t)}\right]^{\mu} D^*(s^t) \right\}^{\nu-1} \\
&\cdot \left\{ [1-N(s^t)]K_0(s^{t-1})^{1-\nu} \int_{\eta_0(s^t)}^{\infty} e^{\left(\frac{1-\nu}{\alpha}\right)\eta}\phi(\eta)d\eta \right. \\
&\left. + N(s^t)K_1(s^{t-1})^{1-\nu} \int_{\eta_1(s^t)}^{\infty} e^{\left(\frac{1-\nu}{\alpha}\right)\eta}\phi(\eta)d\eta \right\}. \qquad (42)
\end{aligned}
$$

Similarly, the aggregate home price $P(h, s^t)$ can be expressed as

$$
\begin{aligned}
\left[\frac{P(h,s^t)}{P(s^t)}\right]^{\frac{\theta}{\theta-1}} &= q(s^t)^{\frac{\theta}{\theta-1}}\left[\frac{P^*(h,s^t)}{P^*(s^t)}\right]^{\frac{\theta}{\theta-1}} + \left[\frac{W(s^t)}{\theta(1-\alpha)}\right]^{\frac{\nu+\theta-1}{\theta-1}} \\
&\cdot e^{\left(\frac{1-\nu}{\alpha}\right)z(s^t)}\left\{\left[\frac{P(h,s^t)}{P(s^t)}\right]^{\mu} D(s^t)\right\}^{\nu-1} \\
&\cdot\left\{[1-N(s^t)]K_0(s^{t-1})^{1-\nu}\int_{-\infty}^{\eta_0(s^t)} e^{\left(\frac{1-\nu}{\alpha}\right)\eta}\phi(\eta)d\eta\right. \\
&\left. + N(s^t)K_1(s^{t-1})^{1-\nu}\int_{-\infty}^{\eta_1(s^t)} e^{\left(\frac{1-\nu}{\alpha}\right)\eta}\phi(\eta)d\eta\right\}. \qquad (43)
\end{aligned}
$$

From the aggregate price index (22),

$$
1 = a_1^{\frac{1}{1-\rho}}\left[\frac{P(h,s^t)}{P(s^t)}\right]^{\frac{\rho}{\rho-1}} + a_2^{\frac{1}{1-\rho}}\left[\frac{P(f,s^t)}{P(s^t)}\right]^{\frac{\rho}{\rho-1}}. \qquad (44)
$$

Values of Firms: Let $V_m(s^t), m = \{0,1\}$, be the average values of firms among the firms that have the same export status, m, in s^{t-1}. Clearly

$$
\begin{aligned}
V_0(s^t) &= \frac{1}{1-N(s^{t-1})}\int V\left[\eta, K_0(s^{t-1}), 0, s^t\right]\phi(\eta)\,\partial\eta, \\
V_1(s^t) &= \frac{1}{N(s^{t-1})}\int V\left[\eta, K_1(s^{t-1}), 1, s^t\right]\phi(\eta)\,\partial\eta.
\end{aligned}
$$

These average values of firms can be rewritten as

$$
\begin{aligned}
V_m(s^t) &= \left[\frac{1-\theta(1-\alpha)}{\theta(1-\alpha)}\right]P(s^t)W(s^t)L_m(s^t) - P(s^t)\left\{[1-n_m(s^t)]K_0(s^t)\right. \\
&\left. + n_m(s^t)K_1(s^t)\right\} + (1-\delta)P(s^t)K_m(s^{t-1}) - n_m(s^t)e(s^t)P^*(s^t)\tau_m \\
&+ \sum_{s^{t+1}} Q(s^{t+1}|s^t)\left\{[1-n_m(s^t)]V_0(s^{t+1}) + n_m(s^t)V_1(s^{t+1})\right\}, \qquad (45)
\end{aligned}
$$

and the difference between $V_1(s^t)$ and $V_0(s^t)$ gives

$$
\begin{aligned}
V_1(s^t) - V_0(s^t) &= \left[\frac{1-\theta(1-\alpha)}{\theta(1-\alpha)}\right]P(s^t)W(s^t)[L_1(s^t) - L_0(s^t)] \\
&- P(s^t)\left\{[n_0(s^t) - n_1(s^t)][K_0(s^t) - K_1(s^t)]\right\} \\
&+ (1-\delta)P(s^t)[K_1(s^{t-1}) - K_0(s^{t-1})] \\
&- e(s^t)P^*(s^t)[n_1(s^t)\tau_1 - n_0(s^t)\tau_0] \\
&+ [n_1(s^t) - n_0(s^t)]\sum_{s^{t+1}} Q(s^{t+1}|s^t)[V_1(s^{t+1}) - V_0(s^{t+1})]. \qquad (46)
\end{aligned}
$$

The conditions for marginal exporters (**??**) can be rewritten as

$$
\begin{aligned}
0 \quad = \quad & \left[\frac{1-\theta(1-\alpha)}{\theta(1-\alpha)}\right] P(s^t) \left[\frac{W(s^t)}{\theta(1-\alpha)}\right]^{\frac{\nu+\theta-1}{\theta-1}} e^{\left(\frac{1-\nu}{\alpha}\right)[z(s^t)+\eta_m(s^t)]} K_m(s^{t-1})^{1-\nu} \\
& \cdot \left\{ \left[\left(\frac{P(h,s^t)}{P(s^t)}\right)^{\mu} D_t + a_2^{\frac{1}{1-\rho}} q(s^t)^{\frac{1}{1-\theta}} \left(\frac{P^*(h,s^t)}{P^*(s^t)}\right)^{\mu} D_t^* \right]^{\nu} \right. \\
& - \left. \left[\left(\frac{P(h,s^t)}{P(s^t)}\right)^{\mu} D_t \right]^{\nu} \right\} - P(s^t)[K_1(s^t) - K_0(s^t)] - e(s^t)P^*(s^t)\tau_m \\
& + \sum_{s^{t+1}} Q(s^{t+1}|s^t)[V_1(s^{t+1}) - V_0(s^{t+1})]. \qquad (47)
\end{aligned}
$$

Notice that by substituting $[V_1(s^{t+1}) - V_0(s^{t+1})]$ with (46), (47) becomes a static equation.

Exports and Imports: The real imports are defined as

$$
(48) \quad IM(s^t) = \int_{i\in\mathcal{E}^*(s^t)} \frac{P(f,i,s_i^t)y(f,i,s^t)}{P(s^t)} di = a_2^{\frac{1}{1-\rho}} \left[\frac{P(f,s^t)}{P(s^t)}\right]^{\frac{\rho}{\rho-1}} D(s^t).
$$

Similarly, the real exports are defined as

$$
(49) \quad EX(s^t) = \int_{i\in\mathcal{E}(s^t)} \frac{e(s^t)P^*(h,i,s^t)y^*(h,i,s^t)}{P(s^t)} di = a_2^{\frac{1}{1-\rho}} q(s^t) \left[\frac{P^*(h,s^t)}{P^*(s^t)}\right]^{\frac{\rho}{\rho-1}} D^*(s^t).
$$

The gross domestic product, $Y(s^t)$ is defined as

$$
(50) \quad Y(s^t) = C(s^t) + I(s^t) + NX(s^t),
$$

where $NX(s^t) = EX(s^t) - IM(s^t)$, the real net exports.

Incomplete Asset Markets: We there is a single non-contingent asset, so the foreign consumer's budget constraint becomes

$$
P^*(s^t)C^*(s^t) + \frac{\overline{Q}(s^t)\overline{B}^*(s^t)}{e(s^t)} \le P^*(s^t)W^*(s^t)L^*(s^t) + \frac{\overline{B}^*(s^{t-1})}{e(s^t)} + \Pi^*(s^t) + P^*(s^t)T^*(s^t).
$$

The first order conditions give

$$
(51) \quad \overline{Q}(s^t) = \sum_{s^{t+1}} Pr(s^{t+1}|s^t) \frac{U_C(s^{t+1})P(s^t)}{U_C(s^t)P(s^{t+1})} = \sum_{s^{t+1}} Pr(s^{t+1}|s^t) \frac{U_C^*(s^{t+1})e(s^t)P^*(s^t)}{U_C^*(s^t)e(s^{t+1})P^*(s^{t+1})}.
$$

And the budget constraint is written as

$$
\begin{aligned}
P^*(s^t)C^*(s^t) + \frac{\overline{Q}(s^t)\overline{B}^*(s^t)}{e(s^t)} \quad = \quad & \left[\frac{1}{\theta(1-\alpha)}\right] P^*(s^t)W^*(s^t)L^*(s^t) - P^*(s^t)I^*(s^t) \\
& + \frac{\overline{B}^*(s^{t-1})}{e(s^t)} - \frac{P(s^t)}{e(s^t)} \left[n_0^*(s^t)\tau_0 + n_1^*(s^t)\tau_1\right] \\
& + P^*(s^t)\left[n_0(s^t)\tau_0 + n_1(s^t)\tau_1\right]. \qquad (52)
\end{aligned}
$$

Hence, The equation for the real exchange rate (19) is replaced by (51), and the budget constraint (52) is newly introduced with the additional variable $\overline{B}^*(s^t)$.

Equilibrium: Under the normalization of price indices, $P(s^t) = P^*(s^t) = 1$, we have 6 dynamic equations[16]:

(39) and foreign analogue for $K_0(s^t)$ and $K_0^*(s^t)$, and $K_1(s^t)$ and $K_1^*(s^t)$;
(46) and foreign analogue for $V_1(s^t) - V_0(s^t)$ and $V_1^*(s^t) - V_0^*(s^t)$; and, 37 static equations:
(13) and foreign analogue for $W(s^t)$ and $W^*(s^t)$;
(19) ((51) under the incomplete asset market condition) for $q(s^t)$;
(23) and foreign analogue for $D(s^t)$ and $D^*(s^t)$;
(33) and foreign analogue for $n_0(s^t)$ and $n_0^*(s^t)$, and $n_1(s^t)$ and $n_1^*(s^t)$;
(34) and foreign analogue for $N(s^t)$ and $N^*(s^t)$;
(35) and foreign analogue for $K(s^t)$ and $K^*(s^t)$;
(36) and foreign analogue for $I(s^t)$ and $I^*(s^t)$;
(37) and foreign analogue for $L_0(s^t)$ and $L_0^*(s^t)$, and $L_1(s^t)$ and $L_1^*(s^t)$;
(38) and foreign analogue for $L(s^t)$ and $L^*(s^t)$;
(42) and foreign analogue for $P^*(h, s^t)$ and $P(f, s^t)$;
(43) and foreign analogue for $P(h, s^t)$ and $P^*(f, s^t)$;
(44) and foreign analogue for $P(s^t)$ and $P^*(s^t)$;
(47) and foreign analogue for $\eta_0(s^t)$, $\eta_0^*(s^t)$, $\eta_1(s^t)$, and $\eta_1^*(s^t)$[17];
(48) and foreign analogue for $IM(s^t)$ and $IM^*(s^t)$;
(49) and foreign analogue for $EX(s^t)$ and $EX^*(s^t)$;
(50) and foreign analogue for $Y(s^t)$ and $Y^*(s^t)$.
With incomplete asset markets we have one more equation for bond holdings
(52) for $B^*(s^t)$.

[16] $Q(s^{t+1}|s^t)$ is substituted by other variables using (14) and (17).
[17] By substituting $[V_1(s^{t+1}) - V_0(s^{t+1})]$ with (46), (47) becomes a static equation.

References

[1] Armington, P.S. (1969): "A Theory of Demand for Products Distinguished by Place of Production," *International Monetary Fund Staff Papers*, 16, 159-178.

[2] Aw, B. Y., S. Chung, and M.J. Roberts (1998): "Productivity and the Decision to Export: Micro Evidence from Taiwan and South Korea," Working Paper 6558, National Bureau of Economic Research

[3] Backus, D., P. Kehoe and F. Kydland (1994): "International Real Business Cycles," *Journal of Political Economy*, 100(4), 745-775.

[4] Backus, D., P. Kehoe and F. Kydland (1994): "Dynamics of the Trade Balance and the Terms of Trade: The J Curve?" *American Economic Review*, 84:84-103.

[5] Backus, D., P. Kehoe and F. Kydland. (1995): "International Business Cycles: Theory and Evidence," in T. Cooley, ed, Frontiers in Business Cycle Research. 331-356.

[6] Baldwin, R. E. (1988): "Hysteresis in Import Prices: The Beachhead Effect," *American Economic Review*, 78(4), 773-785.

[7] Baldwin, R.E. and P. Krugman (1989): "Persistent Trade Effects of Large Exchange Rate Changes," *Quarterly Journal of Economics*, 104(4), 821-854.

[8] Basu, S., and Fernald, J.G. (1994): "Constant Returns and Small Markups in U.S. Manufacturing" International Finance Discussion Paper 483, Board of Governors of the Federal Reserve System.

[9] Baxter, M. (1995) "International Trade and Business Cycles," in Grossman and K. Rogoff, ed., Handbook of International Economics Vol. 3.

[10] Baxter, M., and M. Crucini (1995): "Business Cycles and the Asset Structure of Foreign Trade," *International Economic Review*, 36(4), 821-854.

[11] Bernard, A.B., J. Eaton, J.B. Jensen, and S. Kortum (2003). "Plants and Productivity in International Trade," *American Economic Review*, forthcoming.

[12] Bernard, A.B., and B. Jensen (1995): "Exporters, Jobs and Wages in U.S. Manufacturing: 1976-1987," Brookings Papers on Economic Activity, 1995, 67-112.

[13] ——— (1999a): "Exceptional Exporter Performance: Cause, Effect, or Both?" *Journal of International of Economics*, 47(1), 1-25.

[14] ——— (1999b): "Exporting and Productivity," Working Paper 7135, National Bureau of Economic Research.

[15] ——— (2001): "Why Some Firms Export," Working Paper 8349, National Bureau of Economic Research.

[16] Bernard, A.B., and J. Wagner (1998): "Export Entry and Exit by German Firms," Working Paper 6538, National Bureauof Economic Research.

[17] Chari, V.V., P. Kehoe and E. McGratten. 2001. "Can Sticky Price Models Generate Volatile and Persistent Real Exchange Rates?" Federal Reserve Bank of Minneapolis Staff Report 223.

[18] Das, S., M.J. Roberts. And J.R. Tybout (2001): “Market Entry Costs, Producer Heterogeneity, and Export Dynamics,” Working Paper 8629, National Bureau of Economic Research.

[19] Dixit, A.K. (1989a): “Hysteresis, Import Penetration, and Exchange Rate Pass-Through,” *Quarterly Journal of Economics*, 104(2), 205-228.

[20] Dixit, A.K. (1989b): “Entry and Exit Decisions Under Uncertainty,” *Journal of Political Economy*, 97(3), 620-638.

[21] Heathcote, J. and F. Perri. 2002.”Financial Autarky and International Business Cycles,” *Journal of Monetary Economics*, 49/3, 601-627.

[22] Kehoe, P.J. and F. Perri (2002): “International Business Cycles with Endogenous Incomplete Markets,” *Econometrica*, 70(3), 907-928.

[23] King, R.G., C. L. Plosser, and S. T. Rebelo (1988a): “Production, Growth and Business Cycles, I: The Basic Neoclassical Model,” *Journal of Monetary Economics*, 21(2/3), 195-232.

[24] King, R.G., C. L. Plosser, and S. T. Rebelo (1988a): “Production, Growth and Business Cycles, II: New Directions,” *Journal of Monetary Economics*, 21(2/3), 309-343.

[25] Klein, P. (2000) “Using the Generalized Schur Form to Solve a Multivariate Linear Rational Expectations Model,” *Journal of Economic Dynamics and Control*, 24(10), 1405-1423.

[26] Obstfeld, M. and K. Rogoff. 2000. ”The Six Major Puzzles in International Macroeconomics: Is There a Common Cause” NBER Macroeconomics Annual 2000, 339-390.

[27] Roberts, M.J., and J.R. Tybout (1997): “The Decision to Export in Colombia: An Empirical Model of Entry with Sunk Costs,” *American Economic Review*, 87(4), 545-564.

[28] Stockman, A.C., and L. Tesar (1995): “Tastes and Technology in a Two-Country Model of the Business Cycle: Explaining International Comovements,” *American Economic Review*, 85(1), 168-185.

Year	Starter Ratios			Stopper Ratios			Exporter Ratios		
	US[a]	GR[b]	CO[c]	US[a]	GR[b]	CO[c]	US[a]	GR[b]	CO[c]
1979	-	3.34	-	-	6.45	-	-	37.12	-
1980	-	3.01	-	-	5.95	-	-	36.66	-
1981	-	3.26	-	-	5.93	-	-	37.19	-
1982	-	3.42	-	-	4.93	-	-	37.20	-
1983	-	4.31	2.6	-	6.22	16.8	-	38.10	11.3
1984	-	4.30	2.9	-	5.17	13.5	-	39.19	10.7
1985	-	5.58	4.3	-	4.64	13.1	-	41.59	11.7
1986	-	4.81	3.7	-	5.62	10.8	-	42.96	11.2
1987	13.61	3.79	2.6	14.79	6.39	15.8	48.66	42.91	11.9
1988	16.40	5.29	2.8	12.64	5.18	8.6	50.93	44.12	12.4
1989	12.59	4.74	4.2	12.02	4.86	1.7	50.99	45.14	13.5
1990	14.24	4.21	-	10.83	5.68	-	52.45	44.60	-
1991	13.40	4.21	-	9.48	4.74	-	53.85	45.27	-
1992	16.10	3.64	-	13.48	5.38	-	54.02	44.94	-
Average	14.39	4.14	3.3	12.20	5.51	11.5	51.82	41.21	11.8

Sources: a. Recalculation of Table 5 in Bernard and Jensen (2001); b. Recalculation of Table 2 in Bernard and Wagner (1998); c. Table 2 in Roberts and Tybout (1997).

Notes: Starter ratio – the ratio of non-exporters that transition to exporter status to the number of last period exporters; Stopper ratio – the ratio of exporters that transition to non-exporter status to the number of last period non-exporters; Exporter ratio – the ratio of exporters to the number of all firms.

Table 1: Starter, Stopper, and Exporter Ratios

Preferences	$\beta = 0.99, \quad \sigma = 2, \quad \theta = 0.9, \quad \rho = 1/3, \quad \gamma = 0.294$
Production	$\alpha = 1/3, \quad \delta = 0.025, \quad a_1 = 1, \quad a_2 = 0.321$
Productivity	$M = \begin{bmatrix} 0.95 & 0 \\ 0 & 0.95 \end{bmatrix}$ $Var(\epsilon) = Var(\epsilon^*) = \sigma_\epsilon^2 = 0.007^2$ $Corr(\epsilon, \epsilon^*) = 0.25$ $\sigma_\eta = 0.40$
Trade costs	$\tau_0 = 0.087, \quad \tau_1 = 0.022$

Note: Under the zero export penetration costs, $\tau_0 = \tau_1 = 0$, and $a_2 = 0.315$.

Table 2: Parameter Values

Statistics	Data	No Cost	Cost	TN ($\eta_{1,ave}/\eta_{0,ave}$)	
				1.0437	1.12
Standard deviation (in percent)					
Output	1.72	1.31	1.71	1.77	1.84
Net exports/output	0.15	0.10	0.17	0.30	0.38
Standard deviation (relative to output)					
Consumption	0.79	0.39	0.22	0.20	0.19
Investment	3.24	4.22	5.79	6.38	6.78
Employment	0.63	0.44	0.66	0.67	0.70
Domestic correlation with output					
Consumption	0.88	0.96	0.61	0.59	0.48
Investment	0.93	0.97	0.98	0.96	0.95
Employment	0.86	0.98	0.97	0.98	0.98
Net exports/output	-0.36	-0.43	-0.43	-0.50	-0.52
International correlation					
Output	0.51	0.22	0.43	0.30	0.26
Consumption	0.32	0.53	0.20	0.29	0.30
Investment	0.29	0.05	0.39	0.10	-0.10
Employment	0.43	0.20	0.64	0.38	0.31
Persistence					
Output	0.87	0.68	0.69	0.69	0.69
Consumption	0.85	0.73	0.87	0.91	0.93
Investment	0.91	0.66	0.67	0.66	0.66
Employment	0.95	0.66	0.67	0.66	0.66
Net export/output	0.61	0.70	0.70	0.66	0.65

Table 3: Business Cycle Statistics: Benchmark Model

Statistics	Data	Low	Baseline	High
Standard deviation (in percent)				
Output	1.72	1.71	1.71	1.71
Net exports/output	0.15	0.12	0.17	0.21
Standard deviation (relative to output)				
Consumption	0.79	0.23	0.22	0.22
Investment	3.24	5.67	5.79	5.93
Employment	0.63	0.67	0.66	0.66
Domestic correlation with output				
Consumption	0.88	0.54	0.61	0.64
Investment	0.93	0.98	0.98	0.97
Employment	0.86	0.97	0.97	0.98
Net exports/output	-0.36	-0.38	-0.43	-0.46
International correlation				
Output	0.51	0.50	0.43	0.38
Consumption	0.32	0.15	0.20	0.24
Investment	0.29	0.58	0.39	0.25
Employment	0.43	0.74	0.64	0.55
Persistence				
Output	0.87	0.69	0.69	0.69
Consumption	0.85	0.86	0.87	0.88
Investment	0.91	0.67	0.67	0.67
Employment	0.95	0.67	0.67	0.67
Net export/output	0.61	0.72	0.70	0.69

Notes: Low and high persistence cases have the annual persistence of export status of 75%, and 94%, respectively. The statistics in the data column are from Kehoe and Perri (2002). The model statistics are computed from a simulation of 1000 iterations with 100 periods, where the relevant series have been logged and H-P filtered with a smoothing parameter of 1,600. Net export-output ratios are not logged.

Table 4: Business Cycle Statistics: High and Low Persistence of Export Status

Table 5: Business Cycle Statistics: Sensitivity

Statistics	Data	Baseline		Incomplete		Separable		Spillover	
		No costs	Costs	No costs	Costs	No costs	Costs	No costs	Costs
Standard deviation (in percent)									
Output	1.72	1.31	1.71	1.30	1.68	0.98	1.43	1.47	1.81
Net Exports/output	0.15	0.10	0.17	0.11	0.22	0.06	0.15	0.21	0.33
Standard deviation (relative to output)									
Consumption	0.79	0.39	0.22	0.41	0.26	0.38	0.14	0.50	0.30
Investment	3.24	4.22	5.79	4.25	5.89	3.72	6.09	4.70	6.00
Employment	0.63	0.44	0.66	0.43	0.65	0.20	0.53	0.42	0.57
Domestic correlations with output									
Consumption	0.88	0.96	0.61	0.97	0.62	0.92	0.48	0.89	0.87
Investment	0.93	0.97	0.98	0.97	0.98	0.97	0.98	0.91	0.94
Employment	0.86	0.98	0.97	0.98	0.97	0.67	0.95	0.93	0.98
Net exports/output	-0.36	-0.43	-0.43	-0.48	-0.44	-0.33	-0.43	-0.60	-0.58
International correlation									
Output	0.51	0.22	0.43	0.24	0.48	0.10	0.34	0.02	0.17
Consumption	0.32	0.53	0.20	0.45	-0.07	0.68	0.44	0.77	0.64
Investment	0.29	0.05	0.39	0.06	0.39	0.16	0.25	-0.64	-0.33
Employment	0.43	0.20	0.64	0.27	0.72	-0.31	0.54	-0.58	-0.01
Persistence									
Output	0.87	0.68	0.69	0.68	0.69	0.67	0.68	0.65	0.67
Consumption	0.85	0.73	0.87	0.72	0.84	0.72	0.92	0.70	0.78
Investment	0.91	0.66	0.67	0.66	0.67	0.65	0.67	0.60	0.63
Employment	0.95	0.66	0.67	0.66	0.67	0.70	0.67	0.61	0.64
Net export/output	0.61	0.70	0.70	0.67	0.69	0.94	0.71	0.60	0.62

Notes: The statistics in the data column are from Kehoe and Perri (2002). The model statistics are computed from a simulation of 1000 iterations with 100 periods, where the relevant series have been logged and H-P filtered with a smoothing parameter of 1,600. Net export-output ratios are not logged.

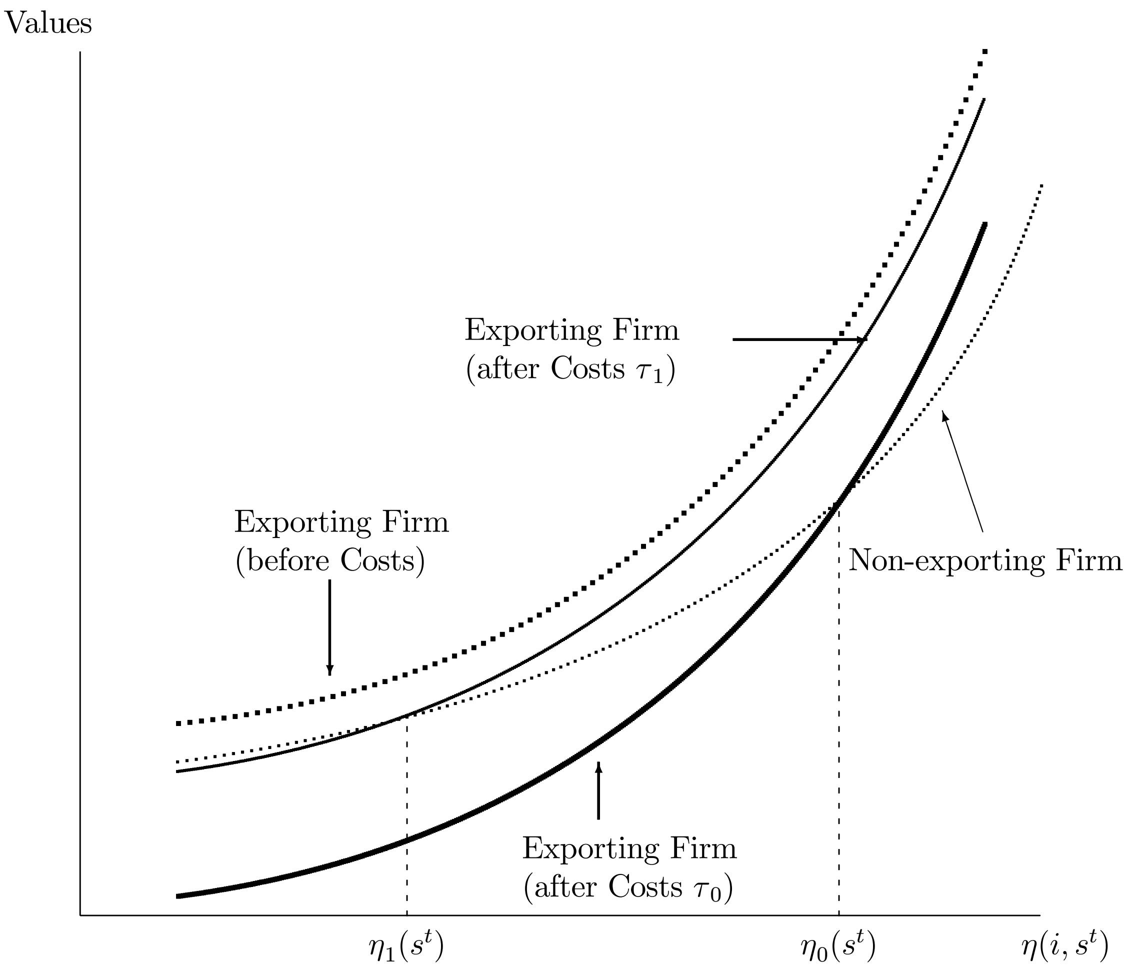
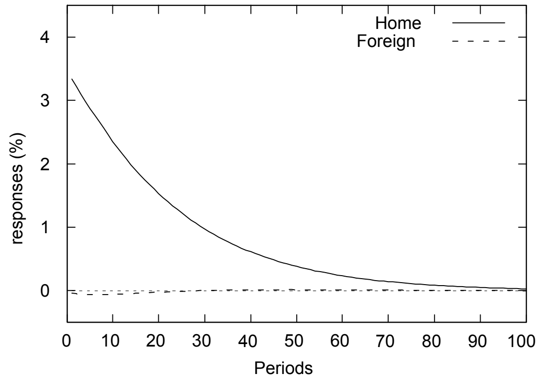


Figure 1: Value of Firms

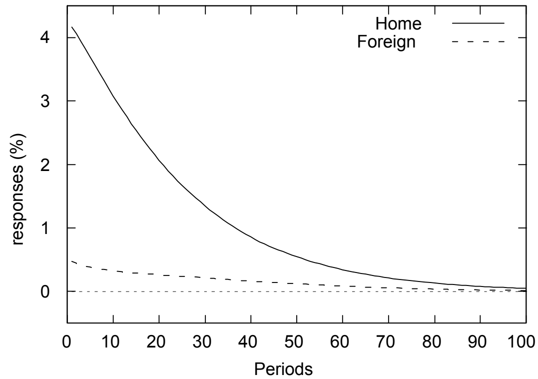
Figure 2: Impulse-response

A. Output

No Cost Model

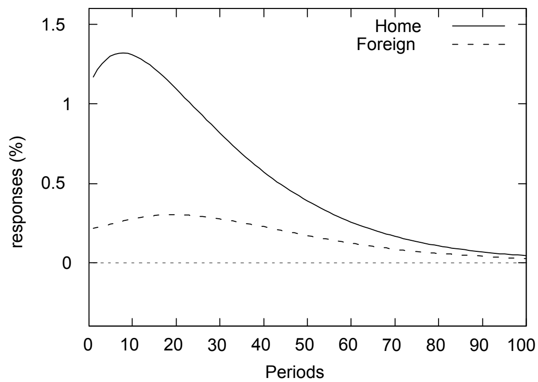


Cost Model

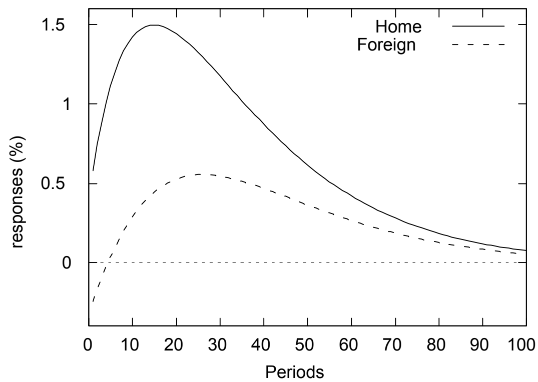


B. Consumption

No Cost Model

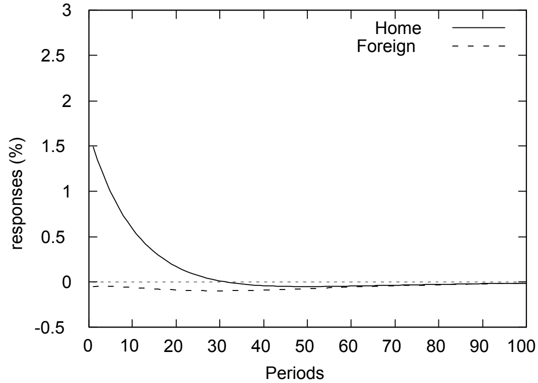


Cost Model

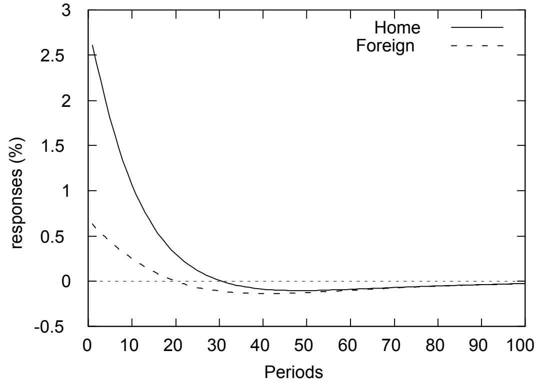


C. Employment

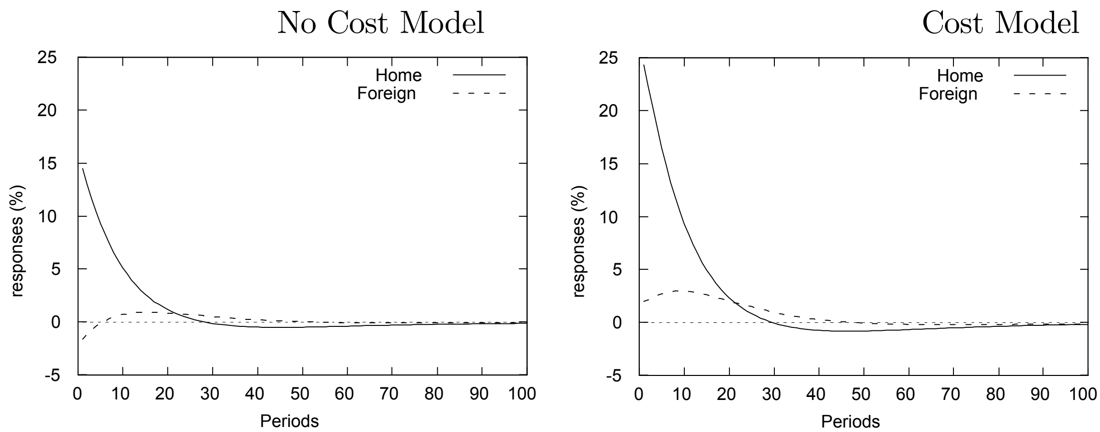
No Cost Model



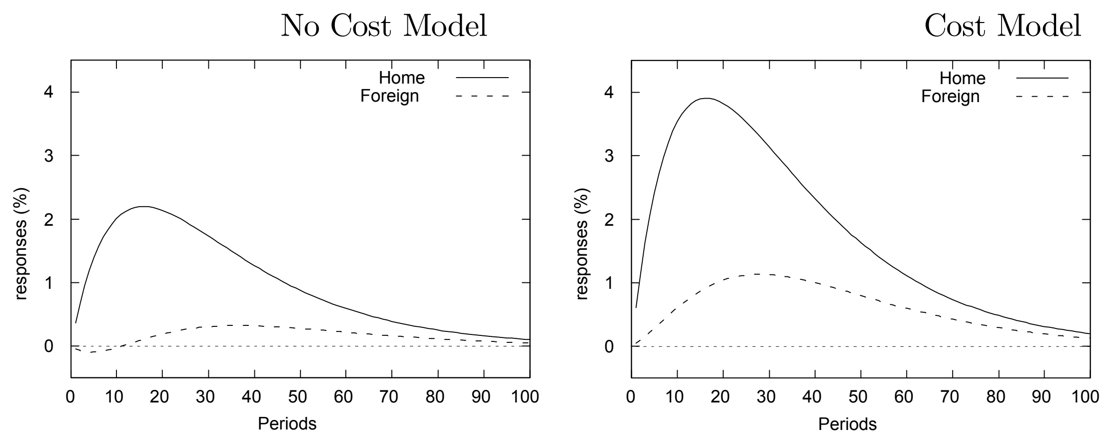
Cost Model



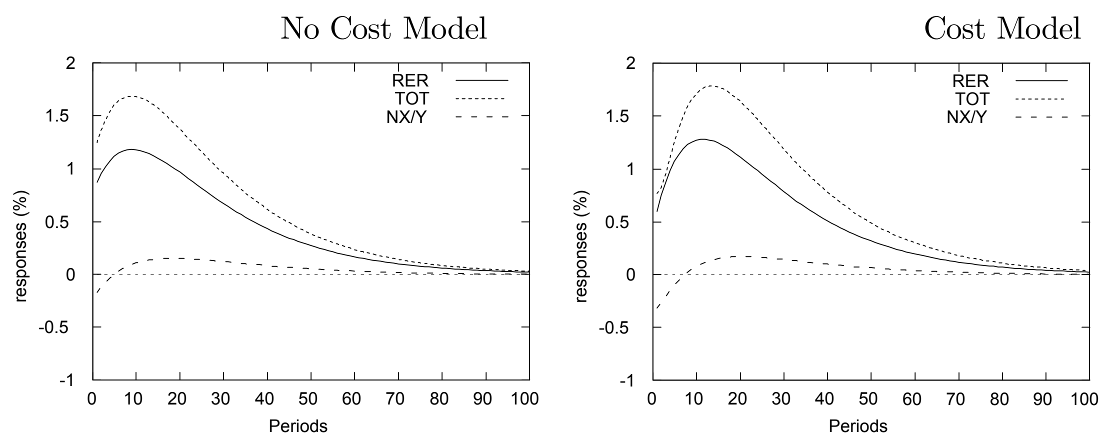
D. Investment



E. Capital

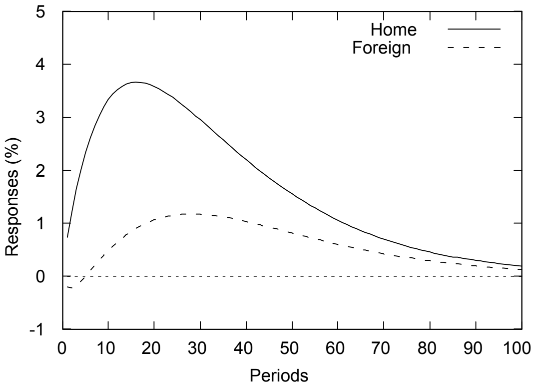


F. Real exchange rates, terms of trade, and net export-output ratio

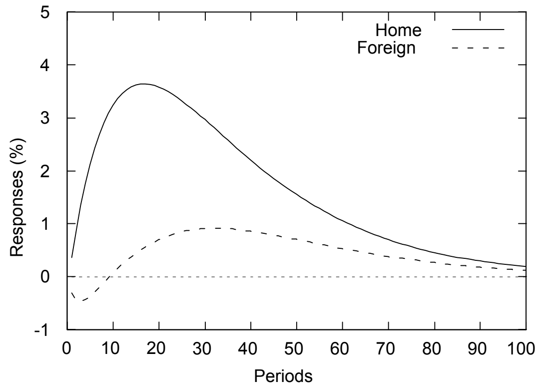


G. Avg Capital Stock of Last Period Non-Exporters and Exporters

K_0

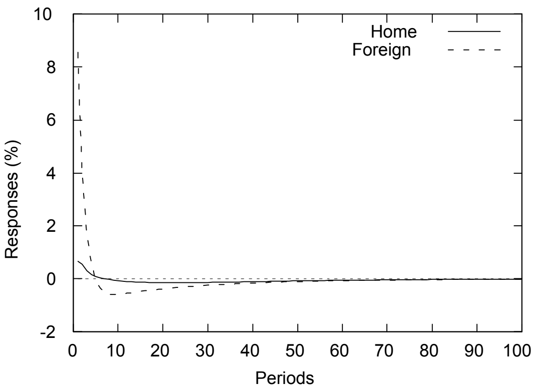


K_1

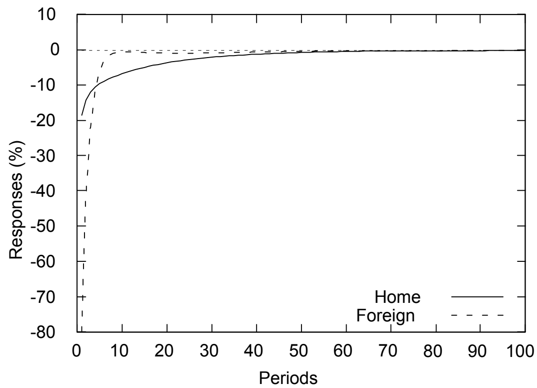


H. Turnover ratios in export status

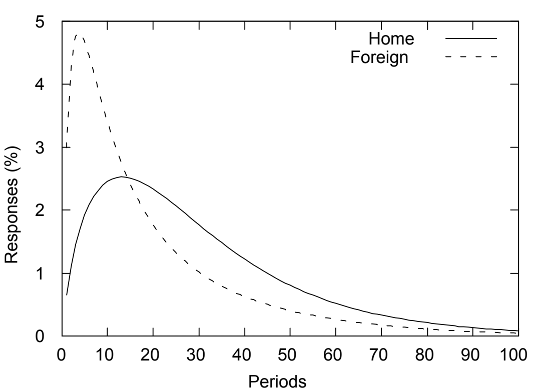
Starter ratios



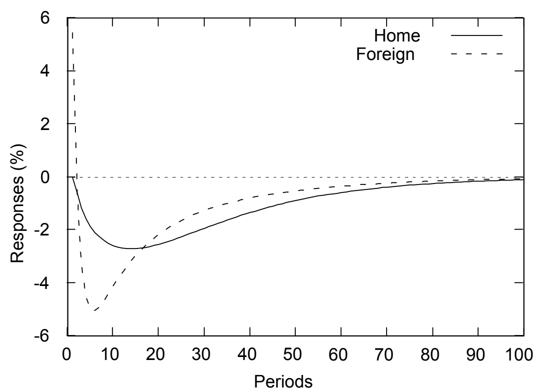
Stopper ratios



Exporter ratios



New exporters $n_0\left(s^t\right)\left(1-N\left(s^{t-1}\right)\right)$



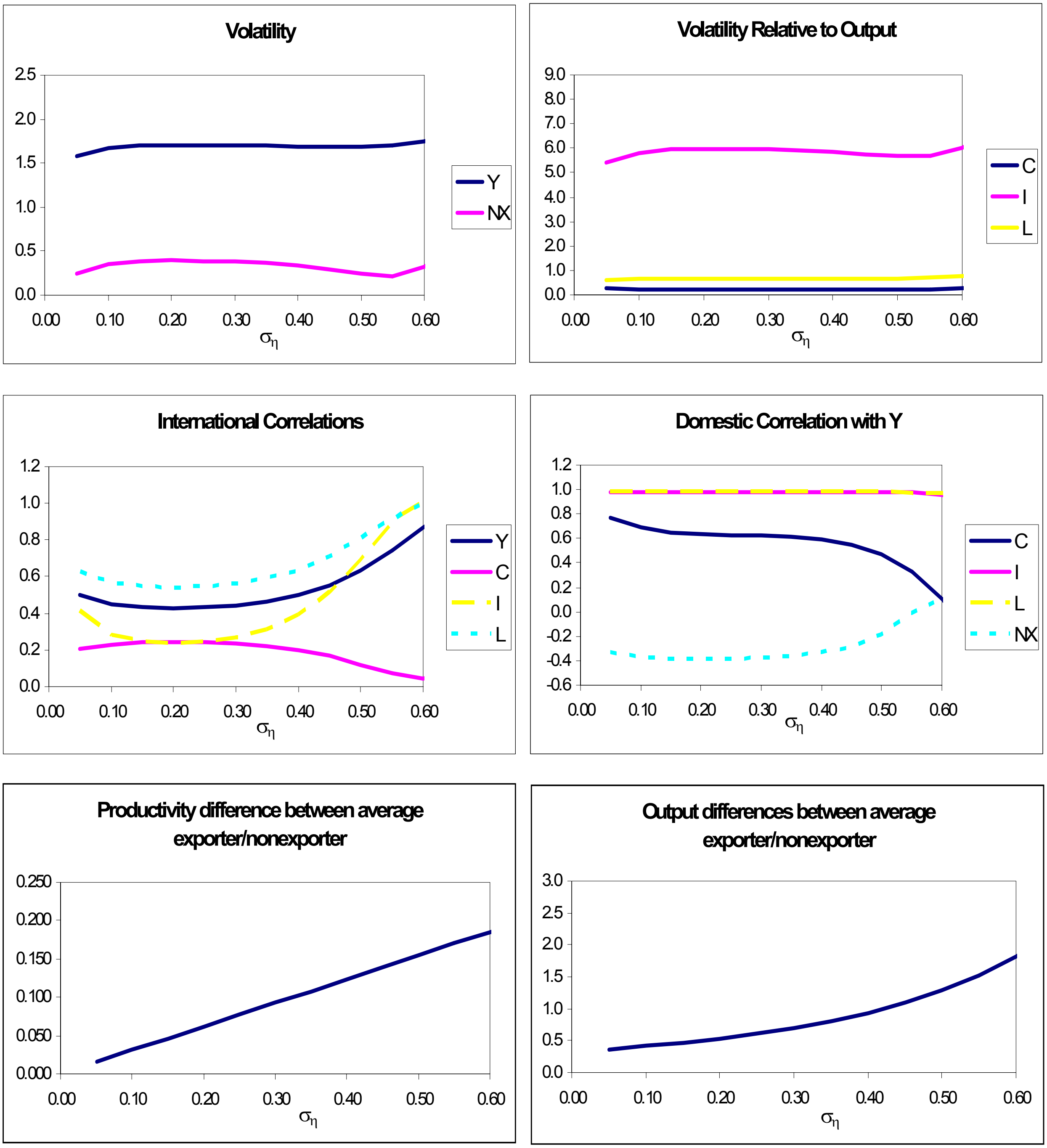


Figure 3: Results from varying volatility of firm specific shock (σ_η)