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**Factor Proportions and International Business Cycles**

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## **Abstract**

Positive investment comovements across OECD economies as observed in the data are difficult to replicate in open-economy real business cycle models, but also vary substantially in degree for individual country-pairs. This paper shows that a two-country stochastic growth model that distinguishes sectors by factor intensity (capital-intensive vs. labor-intensive) gives rise to an endogenous channel of the international transmission of shocks that first, can substantially ameliorate the “quantity anomalies” that mark large open-economy models, and second, generate a cross-sectional prediction that is strongly supported by the data: investment correlations tend to be stronger for country-pairs that exhibit greater disparity in the factor-intensity of trade. In addition, three new pieces of evidence support the central mechanism: (1) the production composition of capital versus labor-intensive sectors changes over the business cycle; (2) the prices of capital-intensive goods and labor-intensive goods are respectively, procyclical and countercyclical; (3) a positive productivity shock in the U.S. tilts the composition of production towards capital-intensive sectors in other countries.

**Keywords:** International business cycles, international comovement, composition effects

**JEL Classifications:** F41, F44

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# 1 Introduction

Studies of international business cycle theory anchored in large-open economy stochastic growth models do not make allowance for differences in factor intensity among goods. The reality is that some sectors use capital more intensively in their production process, while others use labor more intensively. Differences in factor intensity across sectors are large.

A close look at the data reveals some distinctive patterns that mark labor-intensive from capital-intensive sectors. One empirical regularity is that labor-intensive sectors' outputs are much more volatile than capital-intensive sectors' outputs—on average, of about 60%—for a group of OECD countries. Second, there are systematic changes in the *composition* of capital and labor-intensive sectors in the aggregate economy over the business cycle. During booms, the labor-intensive sector expands disproportionately compared to capital-intensive sectors. This is manifested by the strongly countercyclical share of employment in capital-intensive sectors (top panel of Figure 1), and also manifested by its highly countercyclical production share (the bottom panel of Figure 1). The correlation of these employment and production shares are respectively -0.58 and -0.87 for the U.S, and an average of -0.47 and -0.55 for OECD countries.

What this perhaps alerts us to is that there may be systematic differences between capital and labor-intensive sectors, and that making this distinction may be useful in uncovering some largely-ignored facets of business cycles—theoretically and empirically. The changes in the composition of capital and labor-intensive sectors in production, while usually considered to be a long-run phenomenon, is in fact also a recurrent pattern over the business cycle. So far, the international business cycle literature has focused primarily on the division of sectors based on their tradability (tradables vs nontradables) or durability (durables vs non-durables), and applications of such have been wide-ranging and implications far-reaching.<sup>1</sup> Importantly, distinguishing sectors based on their factor intensity of production is not the same as categorizing sectors along the above two characteristics. Neither are capital-intensive goods tantamount to capital goods.<sup>2</sup>

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<sup>1</sup>See Engel and Wang (2011) for business cycle properties of a model with durable and nondurable goods, and Stockman and Tesar (1995) for analyses of a model with nontradable goods.

<sup>2</sup>There is no clear relationship between the durability or tradability of a good with the factor intensity of production. Durable goods can be relatively labor-intensive—for instance, computer and electronic products—or capital-intensive, for example, plastics and rubber products. Similarly, nontradable goods could also be capital-intensive—for example, real estate, utilities, or financial services. Also, the conventional separation of capital goods and consumption goods are based on their end-use, not on intensity of input factors. Some capital goods are also labor-intensive—for instance, computer and electronic products.

Standard two-country models in which there is only one good or multiple goods but with *homogenous* factor intensities cannot account for these robust patterns in the data. Moreover, major discrepancies arise between the theory and the data in the workhorse two-country stochastic growth model of Backus, Kehoe and Kydland (1992) (henceforward BKK). Among these discrepancies, which came to constitute the “quantitative anomalies” of international business cycles (Backus et al. [1993]),<sup>3</sup> investment correlation is arguably the more difficult to replicate in a standard model. While an incomplete-markets setting which allows trade only in noncontingent assets can generate a moderate amount of correlation in output across countries with random walk shocks, as demonstrated by Baxter and Crucini (1995) and Kollman (1996), investment remains to be negatively correlated across countries. At the heart of this divergence is the tendency for resources to flow towards the more productive economy—a “resource shifting effect”—which causes investments to move in opposite directions across countries.<sup>4</sup>

Yet, the positive investment correlation that is observed between the U.S. and an aggregate of OECD countries masks the equally interesting large degree of heterogeneity in this correlation among individual OECD country-pairs. Even among G-7 economies, this correlation can range from 0.15 (U.K.–Italy) to 0.71 (Germany–France) over the period 1972-2005.<sup>5</sup> What can explain this disparity across economies with seemingly similar characteristics?

In this paper, the first objective is to illustrate an endogenous international transmission mechanism that can dominate the resource shifting effect and thereby lead to positive cross-border comovement with a simple extension of the workhorse BKK model, substantially ameliorating the ‘quantity anomalies’ in large open-economy business cycle models. The second objective is to then show that the framework gives a natural cross-sectional prediction of the investment correlations. The framework used to achieve these two theoretical objectives moves away from the one-sector setting to a multiple-sector setting where factor intensities differ across sectors. The new mechanism relies on domestic and international compositional changes and their attendant impact on macroeconomic dynamics. As in the

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<sup>3</sup>The theory predicts negative international comovement in investment, employment and output, while the opposite is true in the data—for the U.S. against a group of European countries.

<sup>4</sup>That productivity shocks may be highly correlated across countries, however, is not the main explanation because various evidence has shown that the cross-country correlation of Solow residuals is lower than that of output. Costello (1993) finds that for five industries in six countries, productivity growth is more correlated across industries within one country than across countries within one industry, and that output growth is more correlated across countries than productivity growth. Evidence based on estimated TFP processes in subsequent works, as well as in this one (Section 4.2), reveals the same pattern. As Stockman (1992) puts it: “the model misses endogenous forces that tend to make foreign and domestic outputs move together (and make their correlation greater than that of technology shocks).”

<sup>5</sup>The G-7 (excluding the U.S.) are Canada, France, Germany, Italy, Japan, U.S., and U.K.. Controlling for importer and exporter fixed-effects, the correlations range from about 0.075 to 0.42.

workhorse framework, goods and international capital flow freely and costlessly across borders.<sup>6</sup> Economies are ex-ante symmetric and produce *all* goods. However, country-specific productivity shocks—which can change the composition of domestic production—also alters the composition of foreign production through international trade. This change in Foreign composition in turn feeds back onto the macroeconomy and determines its investment demand.

For instance, a country hit by a country-specific labor productivity shock—which expands disproportionately its labor-intensive sector<sup>7</sup>—will increase the world supply of labor-intensive goods and hence drive up the world price of the relatively scarcer, capital-intensive goods. Facing a higher relative price for capital-intensive goods, the foreign country expands its production of this sector’s goods by allocating more resources there. This compositional shift in the foreign country—a production structure more tilted towards capital-intensive goods—causes its aggregate demand for investment to rise. Thus, an additional channel driving investment flows emerges: investment resources tend to flow towards the country that has become more capital-intensive in production—a “composition effect”. Moreover, the size of compositional changes observed in the data is roughly in line with what is required by the quantitative model, suggesting that no unrealistic degrees of compositional changes over the business cycle is needed for our channel to operate.

This composition effect—underpinned by *intra-temporal trade*—competes with the standard resource shifting effect—underpinned by *inter-temporal trade*. When the latter effect is the only driving force in the standard models, both inputs and outputs invariably diverge across countries. With multiple sectors, the composition effect can dominate the resource shifting effect, causing investment to rise globally in response to a positive productivity shock in Home.<sup>8</sup>

Figure 2 displays a striking pattern when relating the degree of investment correlation to the similarity in the fluctuations of the capital-intensity of net exports: among G-7

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<sup>6</sup>It is important to note that factor price equalization (FPE) does not occur in this two-country, multiple-sector model with free capital mobility when there is risk and markets are incomplete. Returns to capital are not equalized across countries in the presence of risk. In the complete markets economy, returns to capital are equalized across countries state-by-state—resulting in an indeterminacy of capital at the country level. In this case, we add adjustment costs to break FPE and therefore restore determinacy. We later show that adjustment costs play no material role other than pinning down the capital stock.

<sup>7</sup>Aggregate labor-productivity shocks hit asymmetrically the labor-intensive sector, as is specified by the production function, Eq. 2. However, our focus is not on labor-productivity shocks per se, and will show that under certain conditions similar qualitatively results arise for TFP shocks and sectoral shocks.

<sup>8</sup>The net import of investment resources in the foreign country and its greater production of capital-intensive sectors can also lead to a rise in GDP. Combined with the basic extensions of the model—exogenously restricted asset trade and Greenwood-Hercowitz-Huffman (GHH) preferences, which have failed in resolving these anomalies in the one-sector model—the model can to a great extent resolve the labor comovement and consumption/output anomalies in the multi-sector model.

economies, countries with more similar composition of net exports (in terms of factor intensity) over the business cycle display smaller investment correlations, controlling for importer and exporter dummies.<sup>9</sup> G-7 economies serve as natural specimens for this new channel, as the crucial interaction between trade and investment flows requires an exceptional degree of openness in all respects, at the same time hinging on countries being relatively ‘large’. We expand on this in Section 7.

We begin in Section 2 by documenting some empirical regularities about the behavior of capital and labor-intensive sectors over the short-to medium-run, regularities which are surprisingly little known. We focus on key variables relevant to our mechanism. We find that first, a country-specific productivity shock in the U.S. (and in most OECD economies) expands its domestic labor-intensive sectors by more than it expands its capital-intensive sectors; labor-intensive sectors also tend to be much more volatile than capital-intensive sectors. This delivers the ‘domestic composition effect’ that is necessary to instigate our international transmission channel. Second, evidence indicates that the price of labor-intensive goods is highly countercyclical while the price of capital-intensive goods is highly procyclical for most OECD countries in the sample. Third, employing a structural VAR analysis, we show that a productivity shock originating from the U.S. expands the share of capital-intensive output relative to labor-intensive output *abroad*—here taken to be an aggregate of OECD countries. Together, these empirical regularities suggest that the requisite preconditions that lead to our international transmission channel as well the transmission mechanism itself are met by the data.

The closest framework to ours is the BKK large-open economy model, with complete markets. The only difference is the inclusion of multiple sectors that differ by factor proportions. One extension to the baseline framework is an alternative asset structure in which only one-period bonds can be traded, as in Baxter and Crucini (1995) and Kollman (1996). The endogenous incomplete asset market structure featured in Kehoe and Perri (2002) successfully generates positive international correlations in inputs and outputs.<sup>10</sup> The main

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<sup>9</sup>The graph plots country-pair investment correlations between 1972-2005—controlling for importer and exporter dummies—against the correlation of the factor intensity of net export—calculated as  $\sum_i x_{i,t}^j \alpha_i - \sum_i m_{i,t}^j \alpha_i$  where  $x_{i,t}^j$  and  $m_{i,t}^j$  denote respectively the export and import share of sector  $i$  at time  $t$ , that country  $j$  commands of the U.S. and  $\alpha_i$  is the time invariant capital share of sector  $i$ . Section 7 explains in detail data sources and usage.

<sup>10</sup>The need to satisfy enforcement constraints as international loans are imperfectly enforceable significantly reduces the amount of investment that is accrued to the country hit by a positive and persistent shock—lest the default option should become more attractive.

difference is that our mechanism relies on the interaction between trade and macroeconomic dynamics and is independent of the nature of the asset structure.

The Armington multi-tradable-goods model, the baseline business cycle framework of which is developed by Backus et al. (1994), can generate positive comovement across countries when the elasticity of substitution is unrealistically low or when international asset markets are shut off (financial autarky)—as demonstrated in Corsetti, Dedola and Leduc (2008) and Heathcote and Perri (2000). The main advantage of the current model is that trade and production structure evolves endogenously, compared to the exogenously-rigged, complete specialization structure of trade in the Armington model.<sup>11</sup> One crucial difference is that the transmission of shocks via the terms of trade is central to the Armington model. The rise in foreign investment and output due to a domestic productivity shock relies on the degree of complementarity of the two distinct goods—produced separately in each country. In contrast, the rise in the foreign investment in the current model is largely due to the fact that it produces more *capital-intensive* goods (relative to labor-intensive goods) and thus requires more investment.

International business cycle models that feature endogenous trade dynamics have in the past incorporated heterogeneous firms—as in Ghironi and Melitz (2004),<sup>12</sup> and factor-proportions trade—as in Cuñat and Maffezzoli (2004). The main difference between this paper and Cuñat and Maffezzoli (2004) is that their use of TFP shocks in combination with asymmetries in endowments across countries generates very different initial trade patterns and hence an altogether-different international transmission mechanism. Their main focus is on why the correlation between the terms of trade and income can be positive or negative for different countries—characterized by asymmetries in factor endowments.<sup>13</sup> Jin (2011) applies the two-sector framework in an overlapping generations setting to analyzing the determinants of capital flows across countries over the long run. However, none of these papers examines the behavior of capital and labor-intensive sectors over the business cycle as revealed by the data.

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<sup>11</sup>The Armington model of business cycles also produces the counterfactual result that more trade lead to less output comovement (Kose and Yi [2001]). Another multi-sector model used to investigate international business cycle properties is Ambler et al. (2002). However, sectors do not differ by factor intensity in their model and the model cannot generate positive input and output comovement.

<sup>12</sup>The paper focuses on explaining endogenously persistent deviations from PPP and providing a micro-founded explanation for the Harrod-Balassa-Samuelson effect.

<sup>13</sup>In the absence of the ‘composition effect’ that this paper highlights, positive comovement in inputs and outputs do not emerge in their setting. Their main experiment examines an increase in productivity in the *capital-abundant* country. Since this increase in productivity raises the country’s capital and labor (in efficiency units) by the same proportions, the world’s capital-labor ratio in efficiency units also rises. In contrast, an increase in labor productivity in this economy *reduces* the world’s capital-labor ratio upon impact. Different production and trade patterns ensue, and the resource shifting effect remains the dominant force in their model.

A most rudimentary motive for trade is assumed in this paper. It is by keeping the structure of trade simple that its interactions with macroeconomic forces are most transparent. We are interested in how one realistic dimension of the data—factor intensity differences across sectors—change the implication of international business cycles, although more complex structures of trade can be easily embedded to account for other features of the data.<sup>14</sup>

The paper is organized as follows. Section 2 provides an empirical investigation into the key implication and mechanism of our model. Section 3 extends the standard large open-economy framework to incorporate multiple sectors with heterogenous factor intensities. Section 4 discusses the calibration and parameterization of the model. Sections 5 and 6 examine the dynamic and quantitative properties of the model. Section 7 explores the cross-sectional implications on investment correlations and Section 8 concludes.

## 2 Empirical Regularities of Capital and Labor-Intensive Sectors

In this section, we document some important facts regarding the behavior of capital and labor-intensive sectors over the business cycle. We focus on investigating properties that are key to the central mechanism underscored in this paper. To instigate the international transmission channel, it must be that a country-specific productivity shock expands the domestic labor-intensive sector by more than it expands the capital-intensive sector—the ‘domestic composition effect.’ Second, the motive for expanding capital-intensive industries for an economy in response to a shock abroad is based on an increase in the relative price of capital-intensive goods. We hence examine the cyclicity of labor and capital-intensive goods prices. Third, we examine whether a relative expansion of the capital-intensive industries in response to the shock abroad actually takes place with respect to the U.S. and an aggregate of OECD economies.

Sectoral data is taken from the U.S. Bureau of Economic Analysis Industry Account Dataset, U.S. NBER-CES Manufacturing Industry Database manufacturing productivity dataset and the OECD STAN data. Sectors at the most disaggregated level are categorized into two large groups according to their capital shares in production. Appendix A provides details on the data and the methodology in the construction of these two sectors. For the domestic composition effect, we focus on evidence from the U.S. for the reason that detailed sectoral data for other OECD countries span over a more limited time period and cover a

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<sup>14</sup>An example is vertical integration, featured in Kose and Yi (2001, 2006), Burstein, Kurz and Tesar (2008), Giovanni and Levchenko (2009) and others.



smaller set of comparable industries.

## 2.1 Countercyclical employment and production shares of the capital intensive sector

Figure 3 plots the share of capital-intensive employment in total employment, together with the business cycle indicator measured by real GDP in the U.S., over the period of 1977 to 2009. As in most industrialized countries, there is a steady declining trend in the amount of labor allocated to the capital-intensive sector. However, abrupt reversals in the trend occur during recessions, such that labor is reallocated *towards* the capital-intensive sector (relative to the trend). Moreover, the magnitude of labor reallocation between labor and capital-intensive sectors is not negligible. The reversals are about twice to four times larger than the average annual rate of decline.

Zeroing in on the detrended employment shares, our point of focus, in Figure 1, we find that the share of output and of employment in the capital-intensive sector are strongly countercyclical,  $-0.87$  and  $-0.58$ , respectively. This strong countercyclicity in the output and employment share of capital-intensive sectors is a robust observation across most OECD countries, and robust to alternative levels of sectoral disaggregation. The same pattern can be drawn when focusing on only a subset of the economy—e.g. tradable sectors or manufacturing sectors. Specifically, the output share of capital-intensive tradable sectors is highly negatively correlated with the business cycle ( $-0.67$ ), as is the employment share ( $-0.75$ ). When using the NBER-CES Manufacturing Industry Database which provides the most disaggregated sectoral data on 473 6-digit NACIS manufacturing sectors from 1958-2005, the correlation between the share of employment and output in capital-intensive sectors and output are  $-0.58$  and  $-0.46$  respectively in the two-factor case (capital and labor), and  $-0.43$  and  $-0.52$  in the three-factor case (capital, labor and raw materials).<sup>15</sup>

## 2.2 Cyclicity of Sectoral Prices

Are economic expansions associated with an increase in the relative price of the capital-intensive good or a fall? The cyclicity of goods prices can be revealed by examining the cross-correlation between output and sectoral prices (normalized by overall price index) at different lags and leads, as in Figure 4. Sectoral price indices are calculated as the sectoral

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<sup>15</sup>Appendix B discusses the details of the robustness check.

nominal value-added divided by the real value-added for an aggregate of labor-intensive sectors and an aggregate of capital-intensive sectors, based on data for 59 detailed industries in the U.S. (excluding gasoline related prices).

It is evident that the price of labor-intensive goods is countercyclical and lags the business cycle by two to three years—with the lowest correlation reaching -0.66 in the third year—and the price of capital-intensive goods is procyclical—with the highest correlation with the business cycle as large as 0.69. This pattern also holds for most OECD economies.<sup>16</sup>

### 2.3 Structural VAR analysis: U.S. vs. OECD economies

How does a shock originating from one large economy impact the production composition and structure both domestically and abroad? In answering this question, we examine the responses of the output of capital-intensive sectors (relative to labor-intensive output) to a productivity shock in the U.S., in both the U.S. and an aggregate of OECD countries (henceforward ROW). The methodology adopted is a structural vector autoregression (SVAR) methods, following Galí (1999), Blanchard and Quah (1989) — where technology shocks are identified using long-run restrictions. Based on the standard stochastic growth theory, only technology shocks affect labor productivity permanently—an assumption used to identify technology shocks in the data.

We estimate several specifications of the following structural VAR model:

$$\begin{bmatrix} \Delta x_t \\ \Delta y_t \end{bmatrix} = \begin{bmatrix} C^{11}(L) & C^{12}(L) \\ C^{21}(L) & C^{22}(L) \end{bmatrix} \begin{bmatrix} \Delta \varepsilon_t^a \\ \Delta \varepsilon_t^m \end{bmatrix}$$

where  $x_t$  is the observed (log) labor productivity in the U.S. economy,  $y_t$  is the response variable of interest and  $C(L)$  is a polynomial in the lag operator, and  $\{\varepsilon_t^a\}$  and  $\{\varepsilon_t^m\}$  denote respectively the sequences of technology and non-technology shocks. The long-run restriction that the unit root in productivity originates exclusively from technology shocks implies that  $C^{12}(1) = 0$ . Combined with the normal orthogonality assumption,  $E\varepsilon_t\varepsilon_t' = I$ , it is sufficient to identify  $\varepsilon_t^a$ .

We consider two variables for  $y_t$  – (log) difference between output in capital-intensive sectors and output in labor-intensive sectors in the U.S.,  $\log(Y_k^{US}/Y_l^{US})$ , and the (log) sectoral

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<sup>16</sup>For example, the peak cross-correlation between labor-intensive goods prices (capital-intensive prices) and the business cycle for Canada is -0.23 (0.23), Denmark -0.43(0.44), Finland -0.45 (0.32), Germany -0.67 (0.69), Hungary -0.56 (0.50), Italy -0.49 (0.41), Netherlands -0.65 (0.65), UK -0.16 (0.27).

output differential in the aggregate ROW,  $\log(Y_k^{ROW}/Y_l^{ROW})$ .<sup>17</sup> The standard augmented Dickey Fuller (ADF) tests do not reject the null of a unit root in the levels of either series, but do reject the same null when applied to the first differences at the 1-percent significance level.

Figure 5 shows the effects of the identified technology shocks in the U.S. having a differential impact on output both *across sectors and across countries*. Following a positive technology shock in the U.S., capital-intensive sectors relative to labor-intensive sectors in the U.S. drops and decreases gradually. Together with the evidence presented in Figure 6, this implies that a positive aggregate technology shock, while boosting output in both sectors, disproportionately expands the labor intensive sector. In contrast, the capital-intensive sectors in the ROW expand by more than labor intensive-sectors expand following the positive U.S. productivity shock, as shown in the last panel of Figure 5. This ‘foreign composition effect’ is a critical and distinctive feature of our model.

## 3 Model

### 3.1 Preferences and Technologies

Consider a two-country world, Home and Foreign, each popularized by a large number of identical, infinitely lived consumers. The countries produce the same type of intermediate goods  $i = 1, \dots, m$ , which are traded freely and costlessly, and are conveniently indexed by their labor intensity,  $1 - \alpha_i > 1 - \alpha_j$  for  $i > j$ .<sup>18</sup> Preferences and technologies are assumed to have the same structure across countries.

In each period  $t$ , the world economy experiences one of finitely many events  $s_t$ . Denote  $s^t = (s_0, \dots, s_t)$  the history of events up through and including period  $t$ . The probability, as of period 0, of any particular history  $s^t$  is  $\pi(s^t)$ . Consumers in country  $j$  have the standard preferences

$$\sum_{t=0}^{\infty} \sum_{s^t} \beta^t \pi(s^t) U(c^j(s^t), l^j(s^t)), \quad (1)$$

where  $c^j(s^t)$  denotes consumption per capita and  $l^j(s^t)$  denotes labor respectively at time  $t$ , history  $s^t$  in country  $j$ , and  $\beta$  denotes the discount factor.

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<sup>17</sup>The SVAR estimation for the U.S. uses data over 1977 -2009, whereas that of the ROW uses data over 1992 -2008 due to data limitation. See Data Appendix A for details.

<sup>18</sup>We focus on the case in which countries do not completely specialize in production.

The production technology employs capital and labor to produce an intermediate good  $i$  in country  $j$ :

$$Y_i^j(s^t) = (K_i^j(s^{t-1}))^{\alpha_i} (A^j(s^t) l_i^j(s^t))^{1-\alpha_i}, \quad (2)$$

where  $0 < \alpha_i < 1$ ,  $Y_i^j(s^t)$  is the gross production of intermediate good  $i$  in  $j$  at  $s^t$ ,  $K_i^j(s^{t-1})$  is the aggregate capital stock in sector  $i$  of country  $j$ . Production of intermediate goods is subject to a country-specific random shock  $A^j(s^t)$ , which follows an exogenous stochastic process.

Intermediate goods are combined with an elasticity of substitution  $\theta$  to form a unit of final good, which is used for two purposes: consumption,  $c^j(s^t)$ , and investment, denoted as  $x^j(s^t)$ . The consumption good takes the form of

$$c^j(s^t) = \left[ \sum_{i=1}^m \gamma_i^{\frac{1}{\theta}} (c_i^j(s^t))^{\frac{\theta-1}{\theta}} \right]^{\frac{\theta}{\theta-1}}, \quad (3)$$

where  $c_i^j(s^t)$  is the consumption demand for good  $i$  in  $j$ , and  $\sum_i \gamma_i = 1$ , and  $\theta > 0$ . The investment good in sector  $i$  takes the same form as the consumption good:

$$x_i^j(s^t) = \left[ \sum_{k=1}^m \gamma_k^{\frac{1}{\theta}} (z_{ki,t}^j(s^t))^{\frac{\theta-1}{\theta}} \right]^{\frac{\theta}{\theta-1}},$$

where  $z_{ki,t}^j(s^t)$  denotes the amount of good  $k$  used for investment in the  $i$ 'th sector of country  $j$ . Aggregate investment in country  $j$  at  $s^t$  is  $x^j(s^t) = \sum_i x_i^j(s^t)$ .

Since intermediate goods are traded freely and costlessly across countries, the law of one price holds for each good  $i$ . Let  $p_i(s^t)$  denote the relative price of good  $i$  in terms of the final good. And normalize the price of the final good  $P(s^t)$  to 1 so that

$$P(s^t) = \left[ \sum_{i=1}^m \gamma_i p_i(s^t)^{1-\theta} \right]^{\frac{1}{1-\theta}} \equiv 1. \quad (4)$$

The consumption and investment demand are, respectively:

$$c_i^j(s^t) = \gamma_i (p_i(s^t))^{-\theta} c^j(s^t),$$

and

$$z_{ki}^j(s^t) = \gamma_i (p_i(s^t))^{-\theta} x_i^j(s^t),$$

which, combined with market clearing conditions for intermediate goods, yields the relative price of any two intermediate goods  $i$  and  $k$ :

$$\frac{p_{it}}{p_{kt}} = \left( \frac{\gamma_i \sum_j Y_{kt}^j}{\gamma_k \sum_j Y_{it}^j} \right)^{\frac{1}{\theta}}. \quad (5)$$

The evolution of capital stock in sector  $i$  of country  $j$  follows

$$K_i^j(s^t) = (1 - \delta)K_i^j(s^{t-1}) + x_i^j(s^t) - \frac{b}{2}K_i^j(s^{t-1}) \left( \frac{x_i^j(s^t)}{K_i^j(s^{t-1})} - \delta \right)^2,$$

where  $\delta$  denotes the depreciation rate, and  $b$  denotes the adjustment cost parameter.

Labor market clearing requires that at each date

$$\sum_{i=1}^m l_i^j(s^t) = l^j(s^t)$$

where  $l^j(s^t)$  is total domestic labor at  $s^t$ .

## 3.2 Complete Markets Economy

The benchmark model assumes that a complete set of state contingent securities are traded. Let  $B^j(s^t, s_{t+1})$  denote  $j$ 's holdings of a state-contingent bond purchased in period  $t$  and state  $s^t$  that pays 1 unit of consumption contingent on  $s_{t+1}$  at  $t + 1$ . Let  $Q(s^{t+1}|s^t)$  denote the price of this bond in period  $t$  and state  $s^t$ . Agents in the two economies maximize their expected lifetime utilities, given in Eq. 1, subject to the following constraints:

$$c^j(s^t) + x^j(s^t) + \sum_{s_{t+1}} Q(s^{t+1}|s^t) B^j(s^{t+1}) = B^j(s^t) + w^j(s^t) l^j(s^t) + r^j(s^t) K^j(s^{t-1}),$$

where  $w^j(s^t)$  and  $r^j(s^t)$  are the wage and the net return on capital in country  $j$ . The international bond market-clearing requires that  $\sum_j B^j(s^t) = 0$  for all  $s^t$ .

## 3.3 Bond Economy

In the bond economy, the menu of assets that are traded internationally is exogenously limited to a single non-state contingent bond. The remaining primitives are the same as in the economy described above. The budget constraints associated with the consumer's

problem in this economy are

$$c^j(s^t) + x^j(s^t) + q(s^t)b^j(s^t) = b^j(s^{t-1}) + w^j(s^t)l^j(s^t) + r^j(s^t)K^j(s^{t-1}),$$

where  $q^j(s^t)$  is the period  $t$  price of the uncontingent bond that pays one unit of the consumption good in period  $t + 1$  regardless of the state of the world, and  $b^j(s^t)$  denotes the amount of bonds purchased at  $t$  by a consumer in  $j$ . The international bond market-clearing requires that  $\sum_j b^j(s^t) = 0$  for all  $s^t$ .

## 4 Model Calibration

### 4.1 Preferences and Technology

The benchmark case considers the standard utility function  $U(c, l) = [c^\mu(1-l)^{1-\mu}]^{1-\sigma}/(1-\sigma)$ , and in extensions we also consider quasi-linear preferences, as in Greenwood et al (1988) (GHH), where  $U(c, l) = (c - \kappa l^\psi/\psi)^{1-\sigma}/(1 - \sigma)$ . The GHH preferences allow leisure and consumption to be highly substitutable and eliminate the income effect on labor supply. The procedures used to select benchmark parameter values mostly follow standard approaches of BKK and Kehoe and Perri (2002), except in extending the time frame of the data to 1970-2009, and calibrating parameters relevant for a two-sector setting, as shown in Table 1. The discount rate  $\beta$  is set to 0.99. The risk aversion parameter  $\sigma$  is set at 2 and the depreciation rate at 0.025. The other preference parameters are selected to match the steady-state share of time devoted to labor being one-third, and the (Frisch) elasticity of labor supply being 0.75.<sup>19</sup>

Our benchmark parameterization takes  $\theta = 1$ , which implies that the sector value-added is a constant fraction  $\gamma_i$  of total value-added, and that productivity shocks are neutral at the aggregate level. A strength of our framework is that our main results are insensitive to variations in  $\theta$  (shown in Section 6.2). To compute industry shares and their associated factor intensities, we employ annual industry data at the NAICS 2-4 digit level from the U.S. Bureau of Economic Analysis. There are 61 private sectors at the most disaggregated level. Sectoral labor shares are calculated by dividing the employment compensation by the nominal value-added net operating surplus. The resulting estimates are then averaged across the sample period to obtain time-average labor shares. The capital share,  $\alpha_i$ , is then calculated as one minus the labor share in each sector  $i$ . In aggregating all sectors into two large sectors, we

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<sup>19</sup>The Frisch elasticity of labor supply based on microeconomic evidence is generally small. For example, Pistaferri (2003) finds an elasticity of 0.69, while Blundell and MaCurdy (1999) estimate an elasticity in the range [0.5,1].

assume that the first half is labor-intensive, and the second half capital-intensive. The share of the labor-intensive sector in total value-added,  $\gamma_l$ , is such that  $\gamma_l = \sum_{i=1}^{31} \gamma_i$ , and the share of the capital-intensive sector in value-added is  $\gamma_k = 1 - \gamma_l$ . Factor shares corresponding to the two large sectors,  $\alpha_l$  and  $\alpha_k$ , are calibrated to match the weighted-mean of the capital share of 61 sectors,  $\sum_{i=1}^{61} \gamma_i \alpha_i = 0.39$ , and the weighted variance,  $\sum_{i=1}^{61} \gamma_i (\alpha_i - s_k)^2 = 0.06$ , which captures the degree of factor intensity differences across sectors (the importance of which becomes clear in Section 6.2). The resulting parameterization is  $\gamma_l = 0.55$ ,  $\gamma_k = 1 - \gamma_l = 0.45$ ,  $\alpha_l = 0.17$ ,  $\alpha_k = 0.66$ . Following standard practice, the capital adjustment cost parameter  $b$  is set to match investment volatility relative to GDP volatility as provided by the data.

## 4.2 Productivity shocks

For comparability with the past literature, productivity shocks are taken to be country-specific, as in BKK (1992), Baxter and Crucini (1995), Kollman (1996), Kehoe and Perri (2002), and others. It is important to note that an aggregate labor-productivity shock hits sectors asymmetrically and is biased towards the labor-intensive sector (with a higher exponent  $1 - \alpha_i$  on  $A_j^i$ ) —as revealed by Equation 2. The implication is then that in booms, productivity increases disproportionately the labor-intensive sectors and contracts them disproportionately in recessions, relative to capital-intensive sectors.

We provide three pieces of evidence that rationalize this choice of aggregate fluctuations, which would allow us to stay as close as possible to the previous literature in utilizing country-specific productivity shocks. First, we find that the labor-intensive sectors are more responsive to business cycles than capital-intensive ones: the standard deviation of labor-intensive sectors' real value-added is on average 60% higher than capital-intensives sectors, and the correlation between labor-intensive sectors' real value-added and GDP is 0.95 compared to 0.51 for capital-intensive sectors. Second, direct evidence in Figure 6 indicates that in response to an (orthogonalized) aggregate productivity shock, U.S. labor-intensive sectors' output increases by 1.6% upon impact while capital-intensive sectors' output rises by only 0.5%. Thereafter, labor-intensive sectors continue to expand by more than twice as much as capital-intensive sectors expand, over the entire time horizon.<sup>20</sup> Third, the standard deviation of productivity shocks in labor-intensive industries being higher than that of productivity shocks in capital-intensive industries are also affirmed by results from estimating a VAR (1) process of *sector-specific* TFP using data from U.S. against Canada (Appendix D).

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<sup>20</sup>This pattern holds for most other OECD countries.

It is important to note that the source of aggregate fluctuations is not critical for the main objectives at hand. Be it TFP fluctuations, labor productivity shocks, or sectoral fluctuations, so long as the above composition patterns prevail—patterns which are met by the data—the same transmission of shocks ensues and important quantitative properties are preserved. In Section 6 we demonstrate how this pattern can arise in our model for TFP shocks.

Following BKK (1992), Baxter and Crucini (1995), Kollman (1996), and Kehoe and Perri (2002), we take the technology shocks in the two countries ( $A_t^H, A_t^F$ ) to follow a vector autoregressive (VAR) process of the form

$$\begin{pmatrix} \log A_{t+1}^H \\ \log A_{t+1}^F \end{pmatrix} = \begin{pmatrix} a_1 & a_2 \\ a_2 & a_1 \end{pmatrix} \begin{pmatrix} \log A_{t+1}^H \\ \log A_{t+1}^F \end{pmatrix} + \begin{pmatrix} \epsilon_{t+1}^H \\ \epsilon_{t+1}^F \end{pmatrix},$$

where innovations  $\epsilon_t = (\epsilon_t^H, \epsilon_t^F)$  are serially independent, multivariate normal random variables with contemporaneous covariance matrix  $V$ , which allows for contemporaneous correlation between innovations across countries. Thus the shocks are stochastically related through the off-diagonal element  $a_2$ , the spillover parameter, and the off-diagonal elements of the covariance matrix  $V$ . For the purpose of comparing the results with previous works, we take Kehoe and Perri’s (2002) selection as benchmark, where  $a_1 = 0.95$  and  $a_2 = 0$ . In terms of the covariance matrix, they take  $\text{corr}(\epsilon^H, \epsilon^F) = 0.25$  and  $\sigma(\epsilon_1) = \sigma(\epsilon_2) = 0.009$ .<sup>21</sup>

## 5 Model Dynamics

Impulse responses of domestic and foreign variables to a domestic productivity shock help develop intuition for the key mechanism at hand. To extract it from other confounding factors, we examine the simplest case possible—one with complete asset markets and fixed aggregate labor supply ( $\mu = 0$ ). And in order to add no other impetus for positive co-movement, we first assume that there is zero correlation in the innovations across countries:  $\text{corr}(\epsilon^H, \epsilon^F) = 0$ .

The dynamics of the technology shock is displayed in the lower right panel of Figure 7, which shows that it increases by about 1% and then slowly decreases back to its mean. The productivity of the Foreign country stays the same with the assumption of no spillovers ( $a_2 = 0$ ). On impact, an increase in the aggregate labor productivity in Home hits disproportionately the labor-intensive sector, causing the share of its employment and production in

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<sup>21</sup>Baxter and Crucini (1995) and Kollman (1996) also consider high persistence and little spillovers. Our own estimates from the updated dataset find higher persistence and low spillovers, with  $a_1 = 0.99$  and  $a_2 = 0.004$ . In terms of the correlation between innovations, we find  $\text{corr}(\epsilon^H, \epsilon^F) = 0.298$ ,  $\sigma(\epsilon^H) = \sigma(\epsilon^F) = 0.0079$ .



aggregate employment and production to rise, and conversely, the share of employment and production of the capital-intensive sector to fall (panels 1 and 3). The increase in the world supply of labor-intensive goods drives down its relative price, and raises the relative price of the capital-intensive good (panel 5). In response to the increase in the relative price of the capital-intensive good, Foreign shifts resources towards the capital-intensive sector. On net, Home becomes a net exporter of the labor-intensive intermediate good and Foreign a net exporter of the capital-intensive intermediate good. Thus, an aggregate labor-productivity shock in one country induces compositional changes both domestically and internationally. The same type of dynamics would also arise from a TFP shock that hits all sectors symmetrically if the capital-intensive sector is slower to expand relative to the labor-intensive sector.<sup>22</sup>

These compositional changes impact the aggregate economy and bring about a sharp contrast with the behavior of a one-sector model (Figure 8). As Foreign expands its capital-intensive industry, its demand for investment rises on impact, by about 0.1%. In contrast, in the one-sector model, Foreign investment *falls* sharply, by about 1%, as it flows across-borders towards the more productivity economy—Home. Home’s investment rises in both cases, but by less in the two-sector case (1.5% in the two-sector model compared to the 3.2% in the one-sector model) as investment flows are now shared with Foreign.

A net inflow of investment from Home, combined with domestic resources shifted towards the capital-intensive sector in Foreign substantially increases the output of these goods in Foreign. Foreign’s GDP also rises, in stark contrast to a fall in the one-sector case. The main difference, thus, between the one-sector and two-sector case, is that investment and output tend to rise in both economies in the latter case whereas they tend to move in opposite directions in the former.

Essentially two forces are at work in determining how resources are allocated across countries in the two-sector economy. First is the standard “resource shifting effect”, whereby inputs are shifted towards the more productive economy (investment flows towards Home), making both inputs and outputs move in opposite directions across countries. The second force is induced by changes in the composition of production, causing investment to flow towards the country that features a more capital-intensive production structure—in this case, Foreign. If this “composition effect” dominates the resource shifting effect, investment resources flow towards Foreign on net, and investment rises in both countries. The strength of the composition effect is largely determined by factor intensity differences, and is discussed at length in Section 6.2.

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<sup>22</sup>Note that sectoral shocks that hit all countries symmetrically generate the same compositional changes across countries, and consequently create no impetus for trade.

## 6 Quantitative Properties

This section compares the quantitative properties of the multi-sector model with those of the standard models and the data. We find that incorporating multiple heterogeneous sectors consistently generate international investment comovement. Combined with restricted exogenous asset markets, other quantitative properties become broadly consistent with the data. In Table 2, all data except for international correlations are statistics of U.S. quarterly time series over the period 1970:1-2005:4. International correlations refer to the correlation between a U.S. variable and the same variable for an aggregate of 17 OECD countries (i.e. 15 EU countries, Japan and Canada).

### 6.1 Two Economies with Exogenous Labor

Table 2 reports results for the two-sector, exogenous-labor model with two kinds of asset markets: complete markets and the bond economy. As is clear, positive investment and output comovement are robust across different types of asset structures.

Next we consider whether the results are robust to TFP shocks. A TFP shock which expands both sectors proportionally will not produce the ‘domestic composition effect’ that the labor-intensive sector expands by relatively more than the capital-intensive sector expands—a pattern strongly supported by the data.<sup>23</sup> But even in the presence of TFP shocks, there are reasons to believe that capital-intensive sectors may be less responsive than labor-intensive ones. We explore some plausible explanations in Section 6.4. For our purposes, so long as these domestic composition patterns materialize, the international transmission mechanism through trade and investment flows acts to preserve the quantitative properties of interest. As an illustration we show that assigning higher capital adjustment costs to the capital-intensive sector begets quantitatively similar results, as shown in column (3).<sup>24</sup>

The discrepancies between theory and data that remain are the international correlation of output being smaller than that of consumption (‘consumption/output anomaly’)—and a

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<sup>23</sup>As such, in the absence of the composition effect, investment resources flow to the country that is more productive, and investment diverges across economies. The inflow of capital into the more productive economy, however, benefits more the capital-intensive industries, which then expand by more than the labor-intensive industries. This consequent compositional change is therefore the opposite of what is revealed by the data.

<sup>24</sup>We assume that the industry-specific adjustment cost parameter  $b_i$  is twice as high in the capital-intensive sector as in the labor-intensive sector, while matching the aggregate investment volatility.

counterfactually procyclical trade balance. Naturally, risk sharing with the foreign country implies that domestic consumption and investment do not increase by enough to generate a countercyclical trade balance. These discrepancies can be reduced by restricting asset trade across countries to risk free bonds. As forcefully shown by Baxter and Crucini (1995) and Kollman (1996), the one-good bond economy generates notably different results from the complete markets model only when shocks are close to a random walk. For this reason, we report also results for the case with highly persistent shocks ( $a_1 = 0.99$ ) in Column (5). Both the consumption/output anomaly is resolved and the countercyclical trade balance is restored, in line with results in Baxter and Crucini (1995) and Kollman (1995) in the one-sector economy. However, in their framework, investment correlations across countries remain to be negative whereas they become positive in this two-sector economy. Also, once including endogenous labor (Section 6.3), international labor correlations are also much larger in the two-sector bond economy compared to the one-sector bond economy and can become positive.

To show that adjustment costs do not influence the composition effect in any material way, we shut down adjustment costs ( $b = 0$ ) in the bond economy, persistent shock case, in column (6).<sup>25</sup> Overall, the investment and output comovements are strengthened compared to those of the bond economy cases with adjustment costs. Interestingly, investment is not very volatile even in the absence of adjustment costs in the two-sector economy, for the same reason as in Kehoe and Perri (2002).

### Resource Reallocation and Sectoral Statistics

One may ask whether the model requires unrealistic amounts of sectoral reallocation and compositional changes over the business cycle to generate the right comovements. The last six lines of Table 2 display the sectoral statistics both in the data and from the theoretical model. Capital-intensive sector shares are strongly countercyclical, both implied by the theory and in the data, as reflected by the negative correlation between domestic GDP and their employment shares (-0.47 in the data vs. -0.54 in the bond economy), production shares (-0.32 vs. -0.84) and investment shares (-0.55 vs. -0.20). The volatility of these shares also line up broadly with the data. It shows that one does not need unrealistic fluctuations in sectoral compositions for our channel to operate. The bond economy, for example, moderately overpredicts the relative volatility of employment share of capital-intensive industries (0.59 compared to 0.25 in the data), but underpredicts the volatility of

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<sup>25</sup>In the bond economy with two-sectors and capital mobility, there is no factor price equalization (state by state) in the presence of uninsurable risk. Hence, adjustment costs are no longer necessary to pin down the country-level capital stock.

investment share (0.52 compared to 0.76 in the data), while generating comparable volatility in the production shares (0.54 compared to 0.45).

## 6.2 What drives the strength of the composition effect?

In Table 3 we explore what factors are key in determining the strength of the composition effect, and also explore extensions of the model to include asymmetries across countries. Overall, the most crucial factor is the extent of factor intensity differences across sectors. The more different are factor intensities, the stronger impetus for trade and composition effects, and the higher the cross-country correlations in investment.

### Persistence of Shocks and Parameters

One strength of the current model is that the positive comovement can occur for a wide range of  $\theta$ , both above and below 1. As the goods become more substitutable (high  $\theta$ ), the model behaves more and more like a one-sector economy, and the composition effect is increasingly weakened. As the goods become more complementary (low  $\theta$ ), the greater production of labor-intensive goods in Home also bids a greater production of capital-intensive goods and hence raises *further* Foreign's demand for investment (beyond the composition effect). Investment correlations across countries are thus stronger in the case of lower  $\theta$ . The trade balance is more procyclical with the low elasticity of substitution also because more investment flows towards Foreign. The same can be said about the persistence of shocks. The case that performs the best is the bond economy with highly persistent shocks. With low persistence,  $a_1 = 0.90$  as in the benchmark BKK calibration, investment correlation is stronger but the trade balance also becomes more procyclical (Column (5)).

### Asymmetric Countries

One may ask whether initial asymmetries in factor endowment across economies impact these results.<sup>26</sup> The answer is no, as seen in Table 3, for the reason that the composition effect is largely determined by the *change* in the production and trade patterns rather than initial specialization levels. Whether the labor productivity shock originates from the country with greater labor endowment (Column (6)) or whether it originates from the country with greater capital endowment (Column (7)) matters little. In either case, it is the incremental change in the labor-intensive goods' production and the incremental change in the foreign economy's

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<sup>26</sup>We assume that labor-abundant country's capital-labor ratio is a share 0.87 of the capital-abundant economy's capital-labor ratio. The way to pin down these initial levels is shown in Appendix C.

production of capital-intensive goods that leads to a positive comovement in investment. Initial levels-differences have a negligible impact on this mechanism.

### Factor Intensity Differences and Multiple Sectors

The composition effect is strong when specialization patterns are pronounced, and the extent of specialization depends on factor intensity differences across sectors, in this framework. In the limit where factor intensities converge to the same level, the multi-sector model yields qualitatively similar results to a one-sector model. As factor intensities become more disparate, the composition effect becomes stronger. So how different do factor intensities have to be in order for the composition effect to prevail?

One measure of the dispersion of factor intensities is the weighted variance of  $\alpha_i$ , with  $\sum_{i=1}^m \gamma_i (\alpha_i - 0.39)^2$ , where 0.39 is the weighted-mean of capital intensity,  $\sum_i \gamma_i \alpha_i$ , computed from the sectoral data (described in Section 4.1). The weighted variance as implied from the 61 sectors in the data is 0.06. In order to illustrate that our results hold when extended to a many-sector setting, we calibrate a five-sector model and compute  $\gamma_i$ 's in the same way as the two sector case, and then select  $\alpha_i$ 's to match the weighted mean and the weighted variance of capital share in the data.<sup>27</sup> We then examine the relationship between the cross-sector factor intensity dispersion and investment correlation across the two economies in Figure 9. It shows that as factor intensities become more similar, the resource shifting effect dominates, causing investment to comove negatively across countries. The more different are factor intensities, the more pronounced are composition effects, and the stronger is the investment correlation.

## 6.3 Endogenous labor

In Table 4, we compare the results when allowing for endogenous labor, in the complete markets model, the bond model with standard preferences and the bond model with GHH preferences. Overall, the positive investment comovement remains intact as before. However, labor comovement is negative both in the complete markets model and the bond economy.

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<sup>27</sup>We divide all sectors into five groups and rank them according to factor intensity. Each of the  $\gamma_i$ 's will be the sector value-added, as in the two-sector economy. Then we randomly generate  $\alpha_i$ 's to match the weighted mean and weighted variance in the data. Because of the extra degrees of freedom, there will be no unique correspondance between the weighted variance and the correlation in investment. For this reason, only a linear regression line of simulated correlations is plotted. The purpose of this figure is solely to illustrate the positive relationship between factor intensity differences and the degree of investment correlation.

This strong negative correlation in labor in the complete markets model leads to a negative correlation in output. When introducing GHH preferences to the bond model, the labor comovement becomes moderately positive (0.07 compared to 0.18 in the data), with positive investment correlation (0.13 vs 0.3 in the data), and output correlation (0.23 vs. 0.39 in the data). Consumption and output correlations are now about the same size (0.23). In contrast, investment comovement remains to be negative in the one-sector model, both for the complete markets case and the bond economy.

Figure 10 plots the behavior of labor input following the same aggregate labor productivity shock at Home as before. In the complete markets case, Foreign labor input falls while Home labor rises. With optimal labor insurance in the complete markets equilibrium, the efficient arrangement calls for the less-productive country to work less and consume more. Under complete markets, the strength of the wealth effect in depressing labor input is sufficient to counteract positive substitution effects from the increase in the real interest rate and the wage rate. With GHH preferences and incomplete markets, this wealth effect is shut down, inducing Foreign to increase its labor input on impact in response to an increase in wages.<sup>28</sup>

## 6.4 Discussion

The full setup of the model presented in this paper is a two-country stochastic growth model with multiple tradable sectors which differ in factor intensity. The benchmark, exogenous-labor case with only tradable goods is meant to isolate the main mechanism we highlight from other confounding factors brought about by additional model elements. We follow past literature in allowing for costless trade and investment flows, although we extend the model to include a nontradable sector, presented in Appendix E, and show that the framework is able to generate the right Backus-Smith correlations.

Although with various refinements of the benchmark model, international comovement in investment and output are robust, positive labor comovement is not something that the mechanism emphasized here focuses on addressing. Nor are we arguing that resorting to GHH preferences is necessarily the most satisfactory way to resolve the labor comovement

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<sup>28</sup>The negative correlation in labor is reduced in the bond economy. With restricted risk sharing, foreign country residents do not own productive factors located in the home country. In the absence of international transmission of the productivity shock, there is a zero wealth effect of the shock on foreign consumption and labor supply. Therefore, the substitution effect can lead Foreign to increase its labor supply on impact.

anomaly. However, we do show that these standard extensions of the baseline economy to a large extent succeeds to resolve most anomalies in the two-sector economy. The main point here is that one does not need to stray too far away from the benchmark model and standard assumptions to bring the theory largely in line with the data.

### **TFP shocks**

In the benchmark quantitative analysis we assume that shocks are biased towards labor-intensive sectors, in order to capture their greater response to aggregate fluctuations relative to those of capital-intensive sectors. This pattern is both necessary for the key mechanism in the model and also corroborated by empirical evidence. However, the nature of the shock process is not essential for the main quantitative results so long as it can generate the pattern that labor-intensive sectors expand/contract by more than capital-intensive ones in the shock-originating country. TFP shocks coupled with slower adjustment of capital-intensive sectors compared to labor-intensive sectors deliver similar quantitative results as demonstrated in Section 6.2.

One plausible explanation rests on the well-documented capital-skill complementarity (Krusell et al. [2000]). The relatively low elasticity of labor supply for skilled labor compared to unskilled labor—possibly due to the sunk cost of acquiring skills (Kimball and Shapiro [2008])—as well as more significant labor hoarding (Weinberg [2001]) implies that skilled labor may be a less flexible factor of production compared to unskilled labor, leading capital-intensive sectors to respond less in comparison to labor-intensive sectors. We relegate a more in-depth examination of the causes of these compositional changes to future research, and focus instead on the role they play in the international transmission of shocks.

### **Trade and Business Cycle Synchronization**

An implication of our framework that is not the main focus of this paper but nevertheless important is that more trade leads to greater business cycle synchronization, consistent with the majority of existing empirical findings.<sup>29</sup> Markedly different is the prediction of the Armington two-good model (Backus et al., 1994), in which more trade leads to *less* business cycle comovement, as demonstrated by Kose and Yi (2001). The reason is that lower transportation costs lead to *more* resource reallocation towards the country with the favorable shock—an effect which, all else equal, reduces business-cycle comovement. This force tends to dominate the counteracting force, whereby lower transportation costs are associated with greater trade linkages—hence raising business cycle comovement. By contrast, in our econ-

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<sup>29</sup>For example, see Frankel and Rose (1998), Clark and van Wincoop (2001), Baxter and Kouparitsas (2005), Calderon, Chong and Stein (2007).

omy, more factor-proportions trade tend to raise investment and output comovement. This shows that the *type* of trade may also matter for the degree of business cycle synchronization, and not just the volume of trade, per conventional wisdom.

## 7 Cross-Sectional Implication

Figure 9 shows that the strength of the composition effect compared to the resource shifting effect depends on factor intensity differences. The greater the factor intensity differences across sectors, the greater the impetus for factor-proportions trade between the two economies, and the stronger the composition effect. Thus a natural cross-sectional implication on investment correlation emerges: countries' degree of investment correlation depends on the differences in its factor content of trade.

In the model, the simplest way to capture the strength of the composition effect (relative to the resource shifting effect) is to vary factor intensity differences across sectors—i.e., changing the weighted variance of the capital share. In reality, following a productivity shock in one country—say Germany—the expansion of the capital-intensive sector in another country—say Japan, or the U.K.— may depend on a variety of reasons. If, for some reason, more capital-intensive production (and hence net exports) is undertaken in Japan than in the U.K., Japan's investment would rise by more than that of the U.K., and the investment correlation between Germany and Japan tends to be stronger than that between Germany and the U.K. over time. The difference in the factor content of trade for Germany would also naturally be more different from Japan than from the United Kingdom. In a nutshell, we remain agnostic about the source of fluctuations leading to these compositional changes over the business cycle, but intend to make the main point that the disparity in the factor content of production and trade structure across countries may be associated with their degree of investment comovement.

Arguably G-7 countries are most appropriate for examining this relationship, for two important reasons. The first is that the country has to be relatively 'large', so that shocks originating from that country can influence the relative price of capital and labor-intensive goods, necessary to change the composition of production and trade in other countries. The second prerequisite is openness in trade and capital flows, as the mechanism hinges on the interaction between these two dimensions of trade. The implicit assumption is that the shocks can originate from any of the relatively 'large' countries, and not just say, from the United States.<sup>30</sup>

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<sup>30</sup>If the shocks were predominantly driven by the U.S., then it is possible that the more similar are factor intensity of exports between any other two countries, the higher the correlation in investment between these



The relationship shown in Figure 2 controls for importer and exporter dummies, including any differences in factor endowments. We assume that each country’s factor intensity of trade is largely revealed by its net exports to the United States. Since the rise in investment in a country responding to a shock abroad depends on how much incremental capital-intensive goods it produces and exports (on net) to all other countries—and not just to the corresponding country in that country-pair, one may choose to use U.S.’ (net) imports from that country to more accurately reflect that country’s composition of trade. Moreover, for the same reasons as in Romalis (2004), we use the U.S. trade data because of its quality and its availability and also because the U.S is the largest and most diverse industrial economy, offering the most detailed import data at the SIC87-level with 459 industries. Moreover, the NBER manufacturing dataset is also based on SIC87 division and can therefore be combined with the trade data without any loss of important information.

Specifically, we examine the capital-intensity of net exports, denoted as  $\alpha_{nx}$ , for each non-U.S. G-7 country  $j$ . It is computed as  $\alpha_{nx,t}^j = \sum_i x_{i,t}^j \alpha_i - \sum_i m_{i,t}^j \alpha_i$  where  $x_{i,t}^j$  and  $m_{i,t}^j$  denote respectively the export and import share of sector  $i$  at time  $t$ , in country  $j$ , and  $\sum_i x_{i,t}^j = \sum_i m_{i,t}^j = 1$  and  $\sum_i (x_{i,t}^j - m_{i,t}^j) = 0$  for every  $j$ . The time-invariant capital intensity of industry  $i$ ,  $\alpha_i$ , is computed from U.S. NBER manufacturing dataset and is assumed to be the same for all other G-7 countries.<sup>31</sup> Interestingly, the correlations in  $\alpha_{nx}$ ,  $\text{corr}(\alpha_{nx,t}^i, \alpha_{nx,t}^j)$ , vary widely even among G-7 country-pairs, ranging from -0.41 (Canada-Japan) to 0.53 (Germany-Japan).

As seen in Table 5, the impact of comovement of  $\alpha_{nx}$  is negative and highly significant. Once controlling for country-pair specific correlations in output, the coefficient on  $\text{corr}(\alpha_{nx,t}^i, \alpha_{nx,t}^j)$  becomes more negative. This suggests that the disparity in investment correlations across country-pairs cannot be explained solely by differences in cross-country correlations in innovations. While a thorough empirical investigation of the determinants of investment correlation across countries is beyond the scope of this paper, the main point we highlight is that the heterogeneity in investment correlations may be as interesting in and of itself as the mere fact that it is positive across countries. Also, we provide one channel through which a cross-sectional dispersion may arise even among apriori similar economies, a channel which delivers a prediction that is broadly consistent with the data.

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two economies. However, arguably shocks are not only driven by the United States. Moreover, the data shows that the inverse relationship between capital-intensity of net exports and investment correlations exhibited in Figure 2 also holds between the U.S. and individual G-7 countries.

<sup>31</sup>See Section 2.1 and Appendix A for more details.

## 8 Conclusion

This paper integrates factor-proportions differences across sectors into a two-country stochastic growth model. Endogenous domestic and foreign composition effects, brought about by international trade, lead to a positive transmission of country-specific productivity shocks across countries, dominating the negative transmission of shocks via resource shifting across countries that underlies standard models. The extent of this channel of transmission governs the degree of investment correlation across countries. The quantity anomalies largely disappear with basic extensions of standard models.

In this paper we bring to bear the potentially illuminating act of separating labor-intensive sectors from capital-intensive sectors in investigating facts about business cycles. Composition changes is at once an empirical regularity at the business-cycle frequency – and not only a long-run phenomenon. New empirical findings on the distinctive behavior of capital and labor-intensive industries may serve to be a starting point for a more thorough theoretical and empirical investigation of the nature of sectors marked by differential factor intensities—both in the domestic and international business-cycle context.

## Appendix A Data Sources

### *Aggregate Statistics*

For the economy-wide statistics reported in Table 2, we use quarterly chain-weighted (2005 dollar) NIPA series of GDP, consumption, investment, export and import from the U.S. Bureau of Economic Analysis. Total hours and employment data are from the Organization for Economic Cooperation and Development (OECD) Economic Outlook. The international comovement statistics are calculated using the average statistics between U.S. and individual countries including EU-15, Canada and Japan. For these countries, all quarterly data series are obtained from the OECD Main Economic Indicators. The sample period begins at 1970:1 and ends at 2005:4.

### *Sectoral Statistics*

The sectoral evidence for the U.S. are based on data obtained from the BEA Industry Account Dataset, which provides annual series of nominal/real (chain-type, base year 2005) value-added, price index and components of value-added at NAICS 2-4 digit level from 1977 to 2009. Due to a large methodological break of estimating the value-added price index by the BEA, pre-1987 data are excluded when studying sectoral prices. There are 61 private sectors at the most disaggregated level, among which 38 are classified as tradable sectors according to Stockman and Tesar's (1995) definition of tradable sectors.<sup>32</sup> We use all private sectors in most of our empirical studies, but also confirm that our sectoral evidence does not change significantly once we limit our sectors to tradables only.

Following the standard assumption of Cobb-Douglas production function and competitive markets, time-average capital share at the detailed industry level is constructed as follows:  $\text{Capital share} = 1 - \text{compensation of employees} / (\text{value-added} - \text{taxes less subsidies})$ . All sectors are then recast into one of the two larger sectors: labor-intensive sector if its capital share is lower than the median and capital-intensive sector otherwise. Real/nominal value-added, number of employees are summed up to two sectors. Price indices for the labor-intensive sector and the capital-intensive sector are then calculated by dividing the aggregated nominal value-added over the aggregated real value-added.

Cross-country industry data are taken from the OECD STAN dataset, which publishes annual estimates of sectoral input and output data at ISIC 2-4 digit level for 35 countries. However, only for a smaller set of countries and at the relatively more aggregated sector level, we are able to construct a set of internationally comparable industries. In the end, we have a much smaller number of industries—22 industries—at 2-3 digit ISIC level for

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<sup>32</sup>This includes agriculture, manufacturing, mining, wholesale and retail trade and transportation.

each country. Another drawback of the OECD STAN dataset is even though the dataset dates back to 1970, most major industrial countries do not have detailed sectoral data before 1992. Thus, dictated by availability of comparable sectoral data, our ROW aggregates are constructed based on data from Austria, Canada, Denmark, Finland, France, Germany, Italy, Japan, Netherlands, Norway, Spain and the UK over the 1992-2008 period. For each country, we estimate the country-sector specific capital share as  $1 - \text{labor cost} / (\text{value-added} - \text{net operation profit} - \text{taxes less subsidies})$ .<sup>33</sup> To be consistent with our model, where goods across countries within the same sector have identical factor proportions, we use the cross-country time-average from these calculations. The detailed industries are then divided into two larger sectors according to their fixed capital shares, and input and output estimates are aggregated accordingly. Nominal sectoral value-added of the ROW are aggregated using PPP nominal exchange rates to convert each national nominal sectoral value-added to current U.S. dollars, and then deflated using the sectoral deflator of the U.S. (base year 2000) to obtain the aggregate ROW real sectoral value-added.

#### *Net Exports Data*

U.S. trade with the other G7 economies are taken from Peter Schott's US international industry trade data, which provides SIC87-level U.S. industry export and import data for period 1972-2005. The trade data is then mapped with the NBER-CES Manufacture Industry Data for the estimated sectoral capital intensity.

## **Appendix B    Countercyclical Share of Capital-Intensive Sectors: Robustness**

Previously, we include all 61 private sectors in the economy and group them into a labor-intensive and a capital intensive sector. Among these sectors, 38 sectors are tradable sectors according to Stockman and Tesar's (1995) definition. If we only focus on tradable sectors and categorize labor-intensive and capital-intensive sectors accordingly, we observe the similar cyclical pattern in production patterns: output share of capital-intensive sectors is highly negatively correlated with the business cycle (-0.67), as is the employment share (-0.75).

As noted in Schott (2003), the standard classification of sectors groups goods roughly according to similarity in their end use (in other words, goods that are close substitutes rather than manufactured with similar factor inputs), "a procedure not necessarily consistent with

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<sup>33</sup>Similar to the evidence in the U.S., the estimated capital shares also vary substantially, ranging from 0.08 to 0.83.

the conceptualization of goods in the factor proportions framework”. More disaggregated sectors within the same category often exhibit significant heterogeneity in terms of input intensities. As a robustness check, we use the NBER-CES Manufacturing Industry Database which provides the most disaggregated sectoral data on 473 6-digit NACIS sectors from 1958-2005. We then recast the detailed sectoral data into more theoretically appropriate aggregates according to their input intensities. We consider a two-factor production function with capital and labor and a three-factor production function with raw material input.<sup>34</sup> Although the observations are limited to manufacturing industry and the differences in factor input intensities are reduced, we observe similar patterns as before. Both the share of employment and the share of output in capital-intensive manufacturing sectors strongly negatively comove with the business cycle, with a correlation of -0.58 and -0.46 respectively in the two-factor case, and -0.43 and -0.52 in the three-factor case.<sup>35</sup>

## Appendix C Steady State

A steady state of this economy is its rest point when the variances of the shocks are zero. In a multi-sector world where countries do not fully specialize and factor price equalization holds, the steady state is just the integrated equilibrium parable. The allocation of labor and capital across sectors, in the case of  $\theta = 1$ , are such that

$$\sum_{j=h,f} l_i^j = \frac{\gamma_i(1 - \alpha_i)}{\sum_i \gamma_i(1 - \alpha_i)} \sum_{j=h,f} l^j \quad (6)$$

$$\sum_{j=h,f} K_i^j = \frac{\gamma_i \alpha_i}{\sum_i \gamma_i(1 - \alpha_i)} \sum_{j=h,f} K^j \quad (7)$$

Although the world as a whole is a standard stationary Ramsey economy with a well specified steady state, characterized by a unique world capital to labor ratio, and consumption and labor pinned down at the country level, an infinite number of allocations of capital across countries is consistent with factor price equalization in the steady state, and capital stock is indeterminate at the country level. Although the world stock of employment in sector  $i$  is uniquely pinned down, the allocation of sector  $i$  across economies needs to be selected in

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<sup>34</sup>Data on raw material input are only available for manufacturing industries. Raw material intensity,  $\alpha_m$ , is measured as the value of raw material inputs divided by the sum of raw materials and value-added. Labor intensity and capital intensity, in this case, become  $\alpha_l(1 - \alpha_m)$  and  $(1 - \alpha_l)(1 - \alpha_m)$ .

<sup>35</sup>Instead of considering a two-sector economy, we can also group the most disaggregated sectors into three larger sectors: the most labor-intensive sector, the middle sector and the most capital-intensive sector. Using NBER-CES manufacturing data, we find the correlation between output shares of these sectors with output to be 0.27, 0.30 and -0.44, respectively, and the correlation between employment shares with output to be 0.40, 0.26, -0.68.

order to pin down a unique steady state. The approach taken here is to choose  $x$  such that  $N_i^h/N_0^h = xN_i^f/N_0^f$ , and  $x$  can be chosen to match the relative capital abundance of the two economies. If  $x = 1$ , then the two economies are initially symmetric. If  $N_1^h/N^h > N_1^f/N^f$  where sector 1 is the most capital-intensive industry, then the home country is more capital-abundant than the foreign economy. When factor price equalization holds state-by-state, and at every point along the transition path (the complete markets case), adjustment costs are needed to pin down a unique path of capital. In the case of incomplete markets, the presence of risk does not bring about state-by-state factor price equalization and thus the transitional path is uniquely determined even in the absence of adjustment costs.

## Appendix D Sectoral TFP Shocks Estimation

In the estimation of the VAR(1) model for the series on Home and Foreign sectoral productivity shocks, we use data for the U.S. and Canada. The reason we choose Canada instead of the ROW aggregate is that Canada is the only G7 country (except the U.S.) that has detailed sectoral data regarding real value-added and employment dated back to 1980 (in OECD STAN). If we were to use OECD aggregates, we would only have 16 observations. Estimating a VAR using such limited time period can be problematic. When estimating productivities in labor and capital-intensive sectors, we use the ratio between sectoral real value-added and sectoral total employment obtained from the BEA Industry Database for the U.S. and from the OECD STAN for Canada.<sup>36</sup>

In estimating sectoral TFP shocks in labor and capital-intensive sectors separately, we assume that they follow a trend-stationary AR(1) process:

$$\mathbf{Z}_{t+1} = \mathbf{\Omega}\mathbf{Z}_t + \boldsymbol{\eta}_t$$

where  $\mathbf{Z} \equiv [Z_l^H, Z_l^F, Z_k^H, Z_k^F]$  is a vector of (log) sectoral TFP estimates and has a variance-covariance matrix  $V(\boldsymbol{\eta}_t)$  where  $\boldsymbol{\eta}_t$  is the innovation to  $\mathbf{Z}_{t+1}$ , and  $\mathbf{\Omega}$  is a  $4 \times 4$  matrix of coefficients describing the autoregressive component of the shocks. To be consistent with the model, we impose cross-country symmetry in the structure of  $\mathbf{\Omega}$  and covariances between the elements of  $\boldsymbol{\eta}_t$ . The sectoral TFP shocks are identified using Solow residuals in each sector. The Solow residual in sector  $i$  in country  $j$  and period  $t$ , denoted as  $Z_{it}$  is calculated from

$$\log Z_{i,t}^j = \log Y_{i,t}^j - (1 - \alpha_i) \log L_{i,t}^j - \alpha_i \log K_{i,t}^j$$

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<sup>36</sup>This choice is due to many missing observations for the U.SI, in the OECD STAN dataset.

where  $\alpha_i$  is the sector  $i$ -specific capital share.

The estimation results in  $\Omega = \begin{bmatrix} 0.74 & -0.002 & -0.27 & 0.16 \\ -0.05 & 0.84 & -0.22 & 0.27 \\ -0.27 & 0.16 & 0.74 & -0.002 \\ -0.22 & 0.27 & -0.05 & 0.84 \end{bmatrix}$  and Variance-covariance matrix (in percentage)

$$V(\boldsymbol{\eta}) = \begin{bmatrix} 0.098 & 0.038 & -0.012 & 0.010 \\ 0.038 & 0.071 & 0.010 & 0.020 \\ -0.012 & 0.010 & 0.098 & 0.038 \\ 0.010 & 0.020 & 0.038 & 0.071 \end{bmatrix}.$$

Therefore, the data reveals that the standard deviation of the productivity shocks in the labor-intensive sector is higher than that in the capital-intensive sector. The within-country correlation of innovations across sectors is as large as 0.46, while the cross-country correlation between innovations to sectoral productivities are low, with  $-0.11$  in the labor intensive sector and  $0.29$  in the capital intensive sector. In addition, our estimated productivity shocks are relatively persistent and spillovers across countries and sectors are small.

## Appendix E Adding Nontradable Goods

Since nontradable goods comprise a large share of an economy's output, we incorporate a domestic nontradable sector in each country into the existing framework. Country  $j$ 's production technology combines intermediate tradable goods  $Y_T^j$  and nontradable goods  $Y_N^j$  to form a unit of final good, such that

$$Y^j(s^t) = \left[ \gamma_T^{\frac{1}{\zeta}} (Y_T^j(s^t))^{\frac{\zeta-1}{\zeta}} + (1 - \gamma_T)^{\frac{1}{\zeta}} (Y_N^j(s^t))^{\frac{\zeta-1}{\zeta}} \right]^{\frac{\zeta}{\zeta-1}}, \quad (8)$$

where  $Y_N^j(s^t)$  and  $Y_T^j(s^t)$  denote  $j$ 's aggregate nontradable and tradable output at  $s^t$ . Let the gross output of the nontraded good in country  $j$  be

$$Y_N^j(s^t) = (K_N^j(s^t))^{\alpha_N} (A^j(s^t)N_N^j(s^t))^{1-\alpha_N}, \quad (9)$$

where  $K_N^j(s^t)$  is the aggregate capital stock in the nontradable sector, and  $N_N^j(s^t)$  is the labor used in the nontradable sector in  $j$ , at  $s^t$ , and  $\alpha_N$  is the capital share in the nontradable goods sector.

Only the composite tradable good is used for investment, so that investment in any tradable sector  $i$ ,  $x_i^j(s^t)$ , or the nontradable sector  $N$ ,  $x_N^j(s^t)$ , is  $x_u^j(s^t) = \left[ \sum_{k=1}^m \gamma_i^{\frac{1}{\theta}} (z_{ki}^j(s^t))^{\frac{\theta-1}{\theta}} \right]^{\frac{\theta}{\theta-1}}$ ,

where  $u = i, N$ . The overall consumer price index becomes

$$P_t^j = \left[ \gamma_T (P_{T,t}^j)^{1-\zeta} + (1 - \gamma_T) (P_{N,t}^j)^{1-\zeta} \right]^{\frac{1}{1-\zeta}}, \quad (10)$$

where  $P_{T,t}^j$  is the same as Eq. 4, and is normalized to 1. In equilibrium, both  $p_{it}$  and the relative price of nontraded to traded goods in  $j$  at  $t$ ,  $P_{N,t}^j$ , are determined endogenously.

The additional market clearing condition of the non-traded sector requires

$$Y_{N,t}^j = C_{N,t}^j, \quad (11)$$

that the output of nontradable goods in  $j$  must equal the domestic consumption of that good. The domestic labor market clears when  $\sum_{i=1}^m N_{it}^j + N_{Nt}^j = N_t^j$ . Calibrated to the data that includes all tradable and nontradable sectors, we have  $\alpha_N = 0.41$  and  $\gamma_N = 0.31$  for the nontradable sector, and  $\alpha_l = 0.24$  and  $\alpha_K = 0.58$ , with industry shares  $\gamma_K = 0.31$ , and  $\gamma_l = 1 - \gamma_N - \gamma_k = 0.38$ . The real exchange rate, denoted as  $RER$ , is defined as the ratio of foreign to domestic price level,

$$RER_t = \frac{P_t^F}{P_t^H}.$$

### Real Exchange Rate Dynamics and the Backus-Smith Puzzle

We examine the dynamics of the real exchange rate following a positive productivity shock in Home, and the correlation between the real exchange rate and the Home-to-Foreign consumption ratio in the multi-sector setting, both in the complete markets case and the bond economy, displayed in Table A.1. The multi-sector, bond economy delivers consistently strong and negative correlation between the real exchange rate and the consumption ratio as well as the output ratio ( $-0.85$  compared to  $-0.71$  for the U.S. in the data). In the sensitivity analysis at the bottom half of the table, the results are robust to variations in the elasticity of substitution  $\theta$ , to the persistence of shocks, as well as shutting off adjustment costs ( $b = 0$ ). Once shutting off differences in factor intensity in the tradable sector ( $\alpha_1 = \alpha_2 = 0.3$ ), while assuming a higher labor-intensity in the nontradable sector (setting  $\alpha_n = 0.6$ ) reverses this negative correlation, suggesting that factor intensity differences across tradable goods—important for the composition effect—is key to obtain this negative correlation. We find that the real exchange rate in Home appreciates on impact, and relative consumption decreases.

The positive productivity shock in Home leads to an increase in the supply of all goods—tradable and nontradable. However, most resources are absorbed by the labor-intensive tradable sector, which expands disproportionately as a consequence of aggregate labor-productivity shock. In this case, the increase in the supply of the nontradable goods relative



to tradable goods becomes less than in the one-tradable-sector economy, or multiple tradable-sector economy with the same factor intensities. Therefore, the large increase in the demand for the nontradable good relative to its supply tends to appreciate the relative price of the nontradable good, and hence, the RER. By contrast, a greater increase in the supply of nontradable good relative to its demand tends to depreciate the RER, as in the standard cases. Upon impact, a positive productivity shock causes a RER appreciation, and since the positive shock mostly accrue to Home consumers as a result of incomplete risk sharing, the relative consumption ratio also rises. As Table A.1 shows, the RER and the relative consumption are negatively correlated, a result which is robust to changes in  $\theta$  and the persistence of shocks.

Our emphasis here is not so much in the model’s ability to resolve the Backus-Smith puzzle since the only variation in the real exchange rate in this model is through the fluctuations in the relative price of nontradable goods, and admittedly cannot generate the fluctuations in the price of the tradable goods that play a large role in the data.<sup>37</sup> The purpose, rather, is to illustrate the dynamics of the real exchange rate in a two-sector economy. We show that a positive productivity shock can lead to an *appreciation* of the real exchange rate—in sharp contrast to its behavior in the one-sector model or multi-sector good model with homogenous factor proportions.

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<sup>37</sup>Potentially capable of resurrecting this negative correlation between RER and relative consumption in a two-country incomplete markets model is the setup in Corsetti et al (2008), where Home and Foreign country each specializes in a differentiated good, as in the Armington model—and countries trade only in uncontingent bonds. The main mechanism derives from the interaction between the terms of trade and strong wealth effects that arise from the incomplete markets setting. They show that, in response to a positive shock in the domestic economy, the RER can appreciate when the elasticity of substitution between Home and Foreign goods is low, or, when the elasticity is very high—the addition of highly persistent shocks. The intuition is that, in order for the world market of the Home tradable good to clear, a larger supply of domestic tradables must be matched by an appreciation of the country’s terms of trade that would drive up domestic wealth and hence the demand for domestic goods.

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Table 1: Parameter Values (Baseline Model)

Preferences	$\beta = 0.98, \sigma = 2,$ $\mu = 0.36$ (CD), $\kappa = 1.8, \psi = 2.5$ (GHH)
Production	$\alpha_l = 0.17, \alpha_k = 0.66$ $\gamma_k = 0.45, \theta = 1$
Adjustment costs	$b = 1.5$
Productivity Shocks	$a_1 = 0.95, a_2 = 0$ $\text{var}(\varepsilon^H) = \text{var}(\varepsilon^F) = 0.009^2, \text{corr}(\varepsilon^H, \varepsilon^F) = 0.258$

Table 2: Simulated RBC moments of Two-Sector Model with Fixed Labor

	Data	Complete Markets		Bond Economy		
		Baseline	TFP	Baseline	High Persistence	
		(1)	(2)	(3)	Adj. Cost	No Adj. Cost
	(1)	(2)	(3)	(4)	(5)	(6)
<b>% Standard deviations</b>						
GDP	1.57	0.87	1.72	0.79	0.79	0.79
Net Export/GDP	0.37	0.31	0.70	0.03	0.10	0.05
<b>% Standard deviations</b> (relative to GDP)						
Consumption	0.81	0.36	0.51	0.49	0.76	0.73
Investment	3.33	3.50	3.10	3.35	2.43	2.19
Employment	0.65	–	–	–	–	–
<b>Domestic Comovement</b>						
Correlations with GDP						
Consumption	0.87	0.79	0.65	0.99	0.99	0.99
Investment	0.93	0.96	0.97	0.99	0.98	0.98
Employment	0.88	–	–	–	–	–
Net Exports/GDP	-0.45	0.60	0.39	0.13	-0.34	0.21
<b>International Correlations</b>						
Home and Foreign Y	0.39	0.30	0.19	0.32	0.31	0.32
Home and Foreign C	0.26	1.00	1.00	0.46	0.21	0.15
Home and Foreign I	0.30	0.59	0.32	0.24	0.21	0.57
Home and Foreign N	0.18	–	–	–	–	–
<b>Sectoral Statistics</b>						
<b>% Standard deviations</b> (relative to GDP)						
K-Intensive Employment Share	0.25	0.69	1.10	0.59	0.54	1.54
K-Intensive Production Share	0.45	0.87	0.80	0.54	0.50	1.29
K-Intensive Investment Share	0.76	1.08	0.79	0.52	1.22	20.30
<b>Correlations with GDP</b>						
K-Intensive Employment Share	-0.47	-0.61	-0.19	-0.54	-0.57	-1.46
K-Intensive Production Share	-0.32	-0.94	-0.16	-0.84	-0.89	-0.47
K-Intensive Investment Share	-0.55	-0.55	0.13	-0.20	-0.60	-0.49

*Notes:* The statistics in the data column are calculated from U.S. quarterly time series, 1970:1-2005:4—with the exception of international correlations, which are calculated using data from the U.S. and an aggregate of 17 OECD (EU15, Canada and Japan) countries. The data statistics are based on logged (except for net export to GDP ratio) and HP-filtered data with smoothing parameter of 1600. The model statistics are computed using simulated data (in log and HP-filtered) from a simulation of the model economy of 2000 periods. Parameters are taken from the benchmark case in Table 1.

Table 3: Sensitivity Analysis

		<b>Preference Parameters</b>			
		$\gamma_k = 0.3$	$\gamma_k = 0.6$	$\theta = 2$	$\theta = 0.5$
		(1)	(2)	(3)	(4)
Home and Foreign Y	Complete Markets	0.25	0.27	0.26	0.25
	Bond Economy	0.25	0.38	0.33	0.38
Home and Foreign I	Complete Markets	0.32	0.17	0.22	0.33
	Bond Economy	0.24	0.24	0.22	0.24
Home and Foreign Y-C	Bond Economy	-0.21	-0.08	-0.08	0.02
Corr(NX, Y)	Complete Markets	0.50	0.24	0.10	0.46
	Bond Economy	0.64	0.0	0.0	0.55
		<b>Low Persistence</b>	<b>Initial Endowment</b>		
		$a_1 = 0.90$	Labor-Abundant	Capital-Abundant	
		(5)	(6)	(7)	
Home and Foreign Y	Complete Markets		0.25	0.26	0.25
	Bond Economy		0.29	0.26	0.29
Home and Foreign I	Complete Markets		0.60	0.30	0.30
	Bond Economy		0.42	0.26	0.23
Home and Foreign Y-C	Bond Economy		-0.26	-0.19	-0.04
Corr(NX, Y)	Complete Markets		0.37	0.74	0.40
	Bond Economy		0.62	0.78	0.48

*Notes:* This table reports results when varying various parameters and initial conditions in the two-sector exogenous labor case. Columns (6) and (7) refer to results when the productivity shock originates either from the initially labor-abundant country or the initially capital-abundant country. Corr(NX, Y) refers to the correlation between the trade balance-to-GDP ratio and output.

Table 4: Simulated RBC moments of the Model with Endogenous Labor Supply

	Two Sectors			One Sector	
	Complete Markets	Bond Economy		Complete Markets	Bond Economy
		CD	GHH		
<b>% Standard deviations</b>					
GDP	1.20	1.21	1.13	1.37	1.34
Net Export/GDP	0.42	0.19	0.11	0.36	0.33
<b>% Standard deviations / GDP</b>					
Consumption	0.34	0.43	0.62	0.27	0.29
Investment	3.18	3.40	3.45	3.42	3.24
Employment	0.57	0.50	0.43	0.52	0.49
<b>Domestic Comovement</b>					
Correlations with GDP					
Consumption	0.87	0.97	0.99	0.90	0.94
Investment	0.95	0.97	0.97	0.95	0.95
Employment	0.96	0.96	0.99	0.99	0.99
Net Exports/GDP	0.66	0.57	-0.13	-0.02	-0.05
<b>International Correlations</b>					
Home and Foreign Y	-0.06	0.11	0.23	0.09	0.12
Home and Foreign C	0.79	0.44	0.23	0.17	0.62
Home and Foreign I	0.12	0.23	0.13	-0.17	-0.09
Home and Foreign N	-0.60	-0.37	0.07	-0.05	-0.04
<b>Sectoral Statistics</b>					
<b>% Standard deviations</b> (relative to GDP)					
K-Intensive Employment Share	0.69	0.61	0.57	–	–
K-Intensive Production Share	0.87	0.54	0.94	–	–
K-Intensive Investment Share	1.08	0.56	1.69	–	–
<b>Correlations with GDP</b>					
K-Intensive Employment Share	-0.61	-0.64	-0.63	–	–
K-Intensive Production Share	-0.94	-0.89	-0.90	–	–
K-Intensive Investment Share	-0.55	-0.58	-0.56	–	–

*Notes:* Model statistics for the endogenous labor case are computed using simulated data (in log and HP-filtered) from a simulation of the model economy of 2000 periods. Parameters are taken from the benchmark case in Table 1.



Table 5: Cross-Section Investment Correlations and Composition of Trade Correlations

	(1)	(2)
$\text{corr}(\alpha_{nx,i}, \alpha_{nx,j})$	-.309*** (.070)	-.320*** (.065)
$\text{corr}(y_i, y_j)$		.252** (.122)
const	.256*** (.057)	.167*** (.068)
Number of Obs	15	15
$R^2$	0.79	0.83

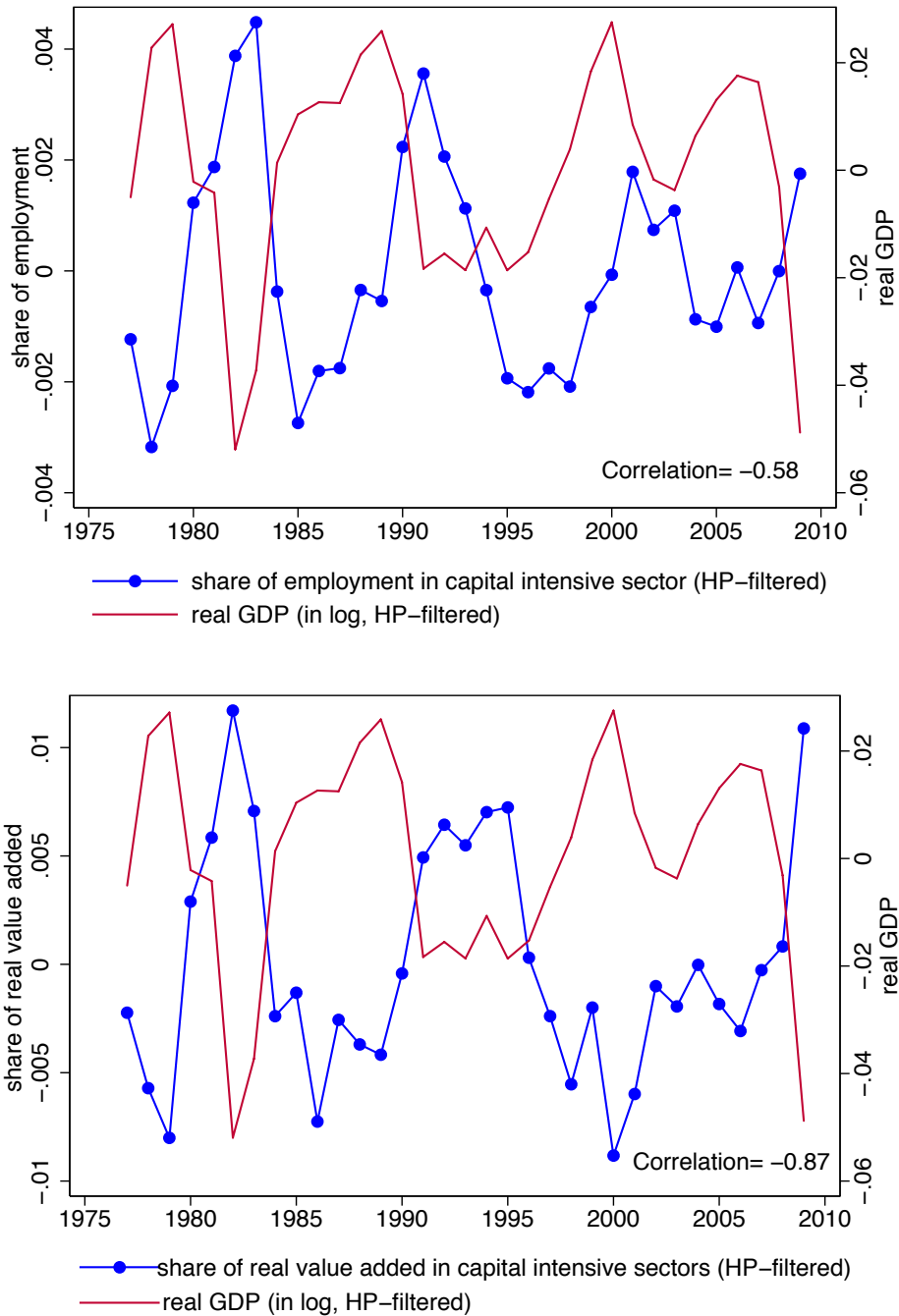
*Notes:* The dependent variables are the investment correlations across country-pairs. Regressions control for exporter and importer dummies. Robust standard errors are reported in brackets. \*\*\* indicates significance at the 1 percent level; \*\* indicates significance at the 5 percent level.

Table A.1: Backus-Smith Puzzle: Correlation between RER and Relative Consumption

Baseline Experiment	Data	One Sector	Multi-Sector		
			Complete Mkt	Bond Economy CRRA	GHH
$\text{Corr}(RER, \frac{C^H}{C^F})$	-0.71	0.88	0.95	-0.86	-0.88
$\text{Corr}(RER, \frac{Y^H}{Y^F})$	-0.19	0.93	0.93	-0.87	-0.88
Sensitivity	<b>Multi-Sector Bond Economy (CRRA)</b>				
	$\theta = 0.5$	$\theta = 1.5$	High Persistence	b=0	$\alpha_1 = \alpha_2$
$\text{Corr}(RER, \frac{C^H}{C^F})$	-0.86	-0.86	-0.85	-0.30	0.88
$\text{Corr}(RER, \frac{Y^H}{Y^F})$	-0.87	-0.87	-0.86	-0.30	0.79

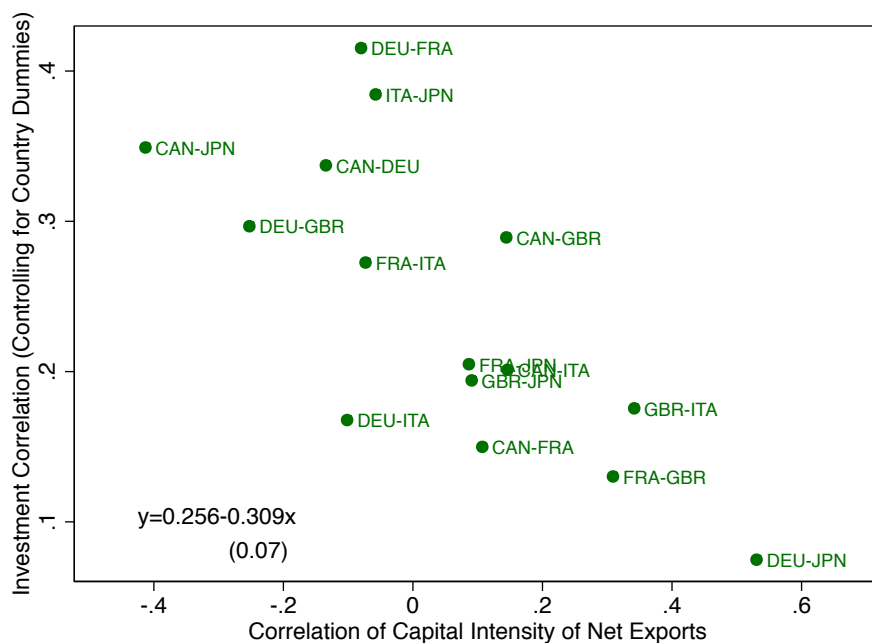
*Notes:* The data represents the correlation for U.S. against ROW, taken from Corsetti et al (2008). Model statistics between the real exchange rate ( $P^F/P^H$ ) and relative consumption in the bond economy-GHH preferences case are computed using simulated data.

Figure 1: Compositional Changes and the Business Cycle



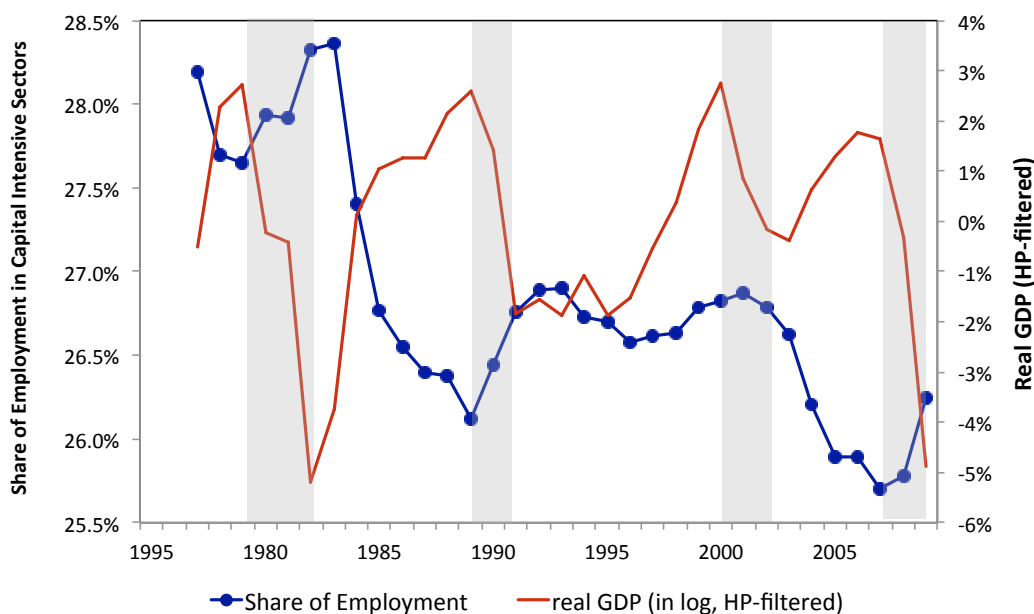
*Notes:* Data source: U.S. BEA Industry Economic Accounts. Sixty-one private sectors at the most disaggregated level (NAICS 2-4 digit) are divided and aggregated into two larger sectors—labor-intensive and capital-intensive sectors. See Appendix A for more details.

Figure 2: Investment Correlations and Correlations in the Dynamics of Trade Composition (1972-2005)



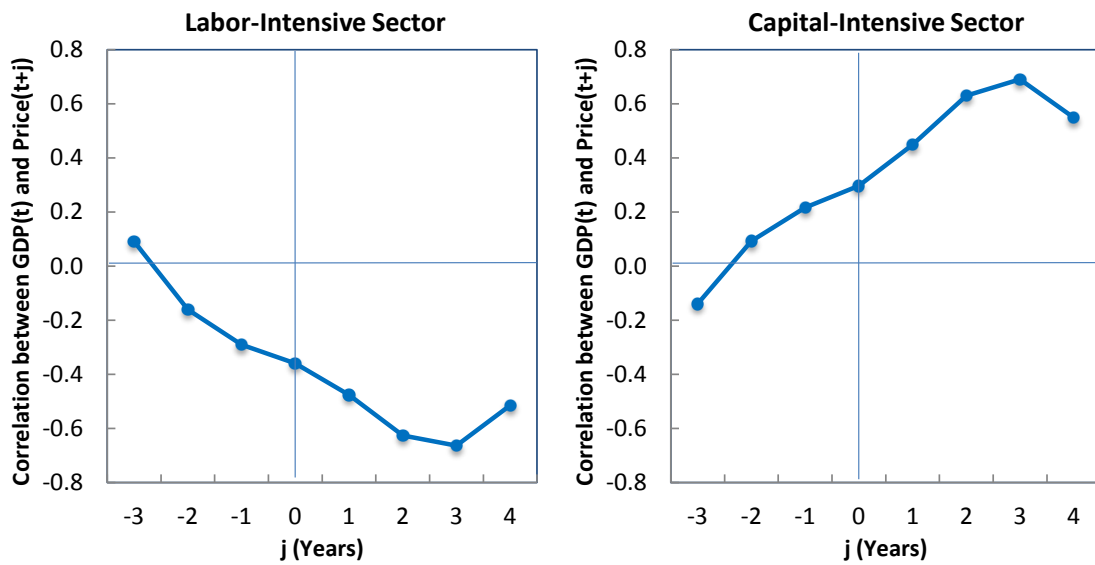
Notes: Data source: NBER-CES Manufacturing Industry Data, U.S. International Industry Trade Data by Peter Schott and OECD MEI dataset. Capital intensity of net exports is constructed as  $\sum_i x_{i,t} \alpha_i - \sum_i m_{i,t} \alpha_i$ , where  $x_i$  ( $m_i$ ) stands for the share of export (import) of sector  $i$  and  $\alpha_i$  is the capital intensity of sector  $i$ .

Figure 3: Capital-intensive Employment Share



Notes: The shaded area marks the start till the end of the economic downturn according to (HP-filtered) real GDP (red line).

Figure 4: Cross-correlation between GDP and Sectoral Prices



*Notes:* Sectoral price indices are constructed as the sectoral nominal value-added divided by the real value-added for an aggregate of labor-intensive sectors and an aggregate of capital-intensive sectors, which are then normalized by the overall price index. Data source: U.S. BEA Industry Account Data, excluding oil related industries: Utilities, Oil and gas extraction and Petroleum and coal productions.

Figure 5: Estimated Impulse Responses to a Productivity Shock in the U.S.

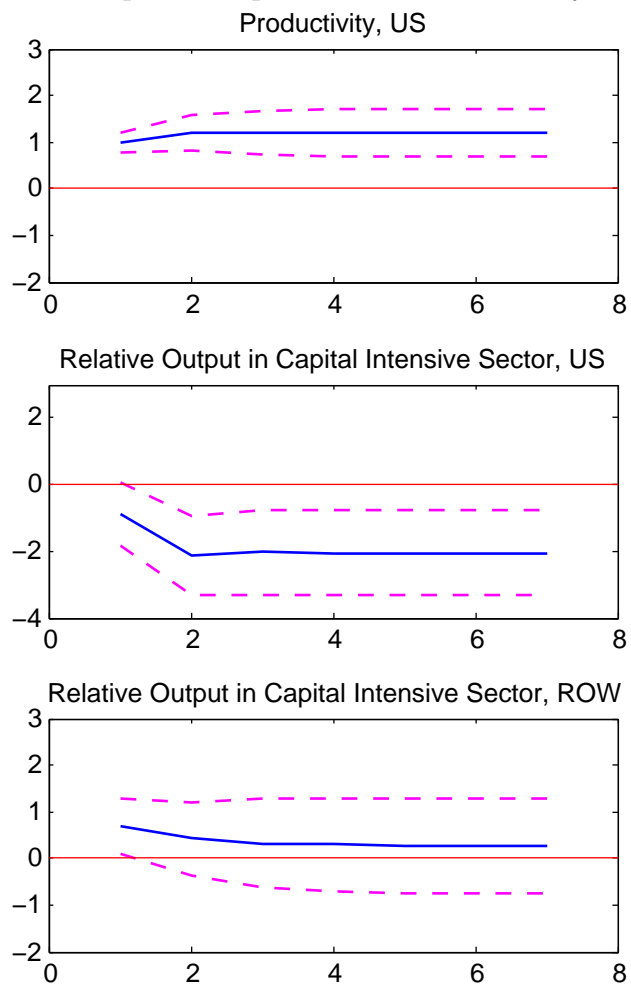


Figure 6: Impulse Responses to a (Orthogonalized) one s.d. U.S. Productivity Shock

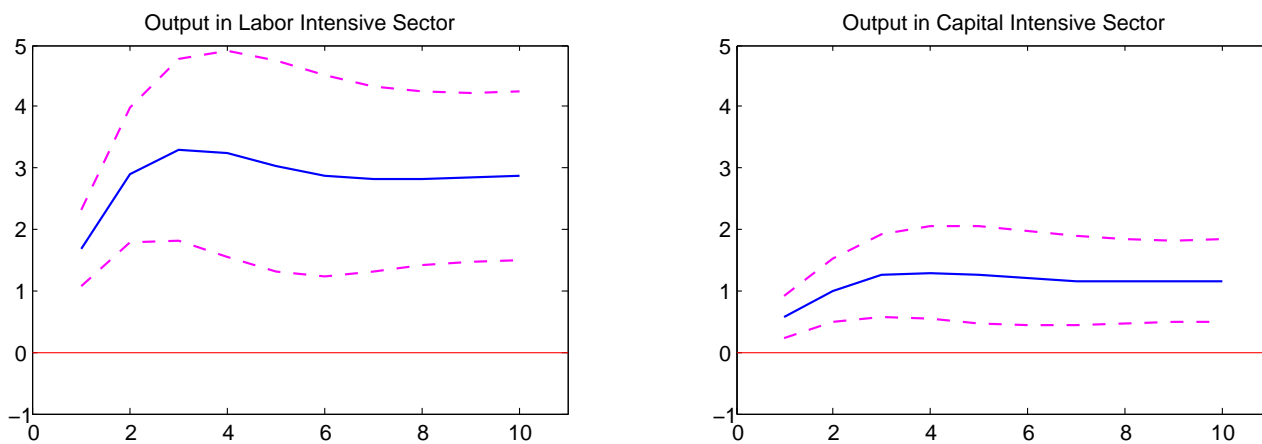


Figure 7: Impulse Responses to a Home Productivity Shock—Sectoral Variables, Fixed Labor Supply

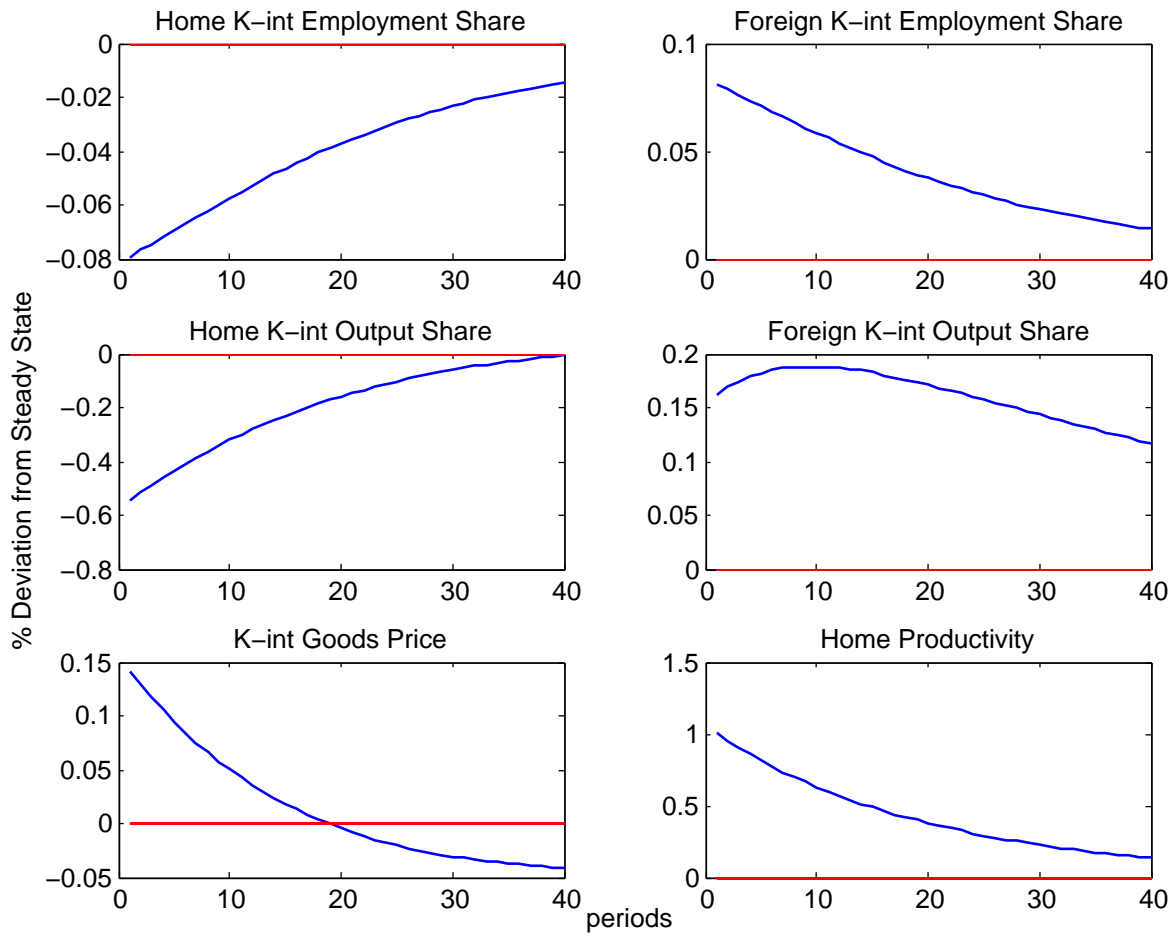


Figure 8: Impulse Responses to a Home Productivity Shock—Economy-wide Variables, Fixed Labor Supply (One-Sector vs. Two-Sector Case)

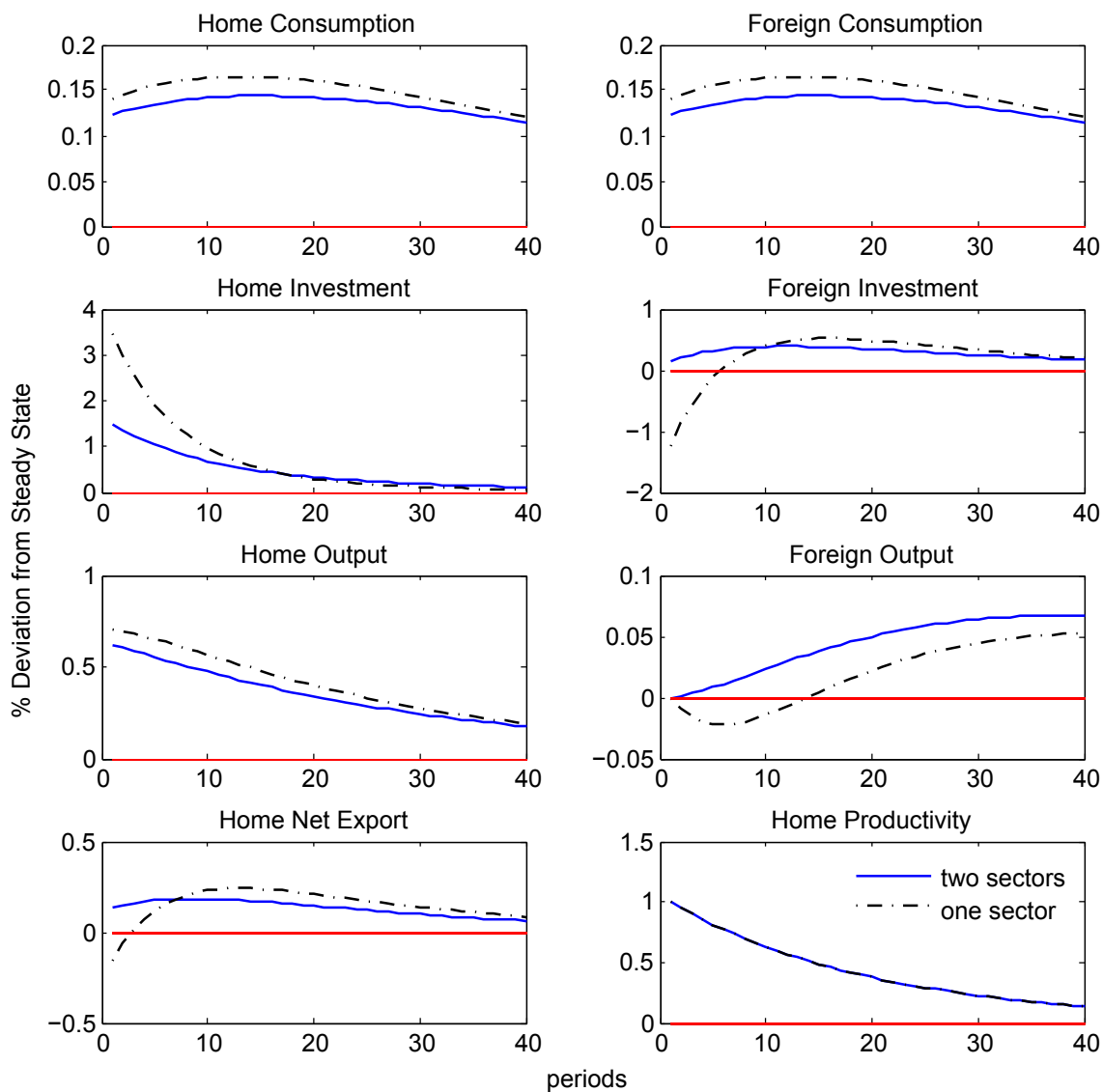


Figure 9: Investment Correlation and Factor Intensity Differences

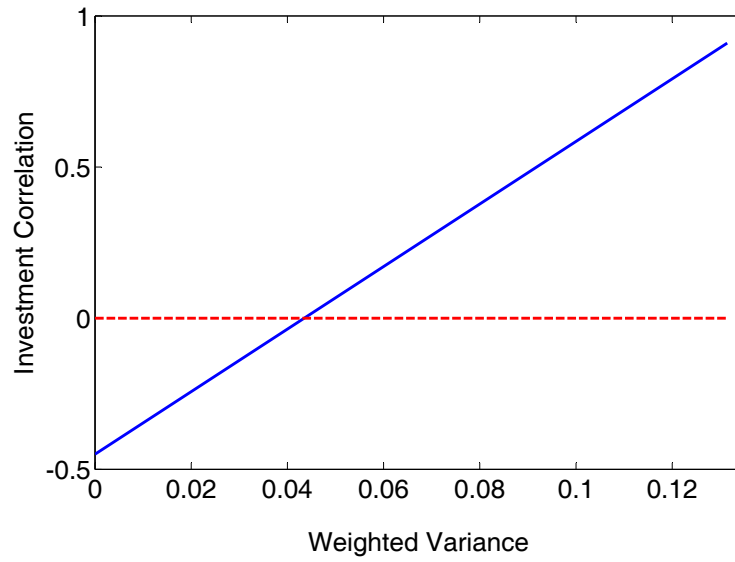
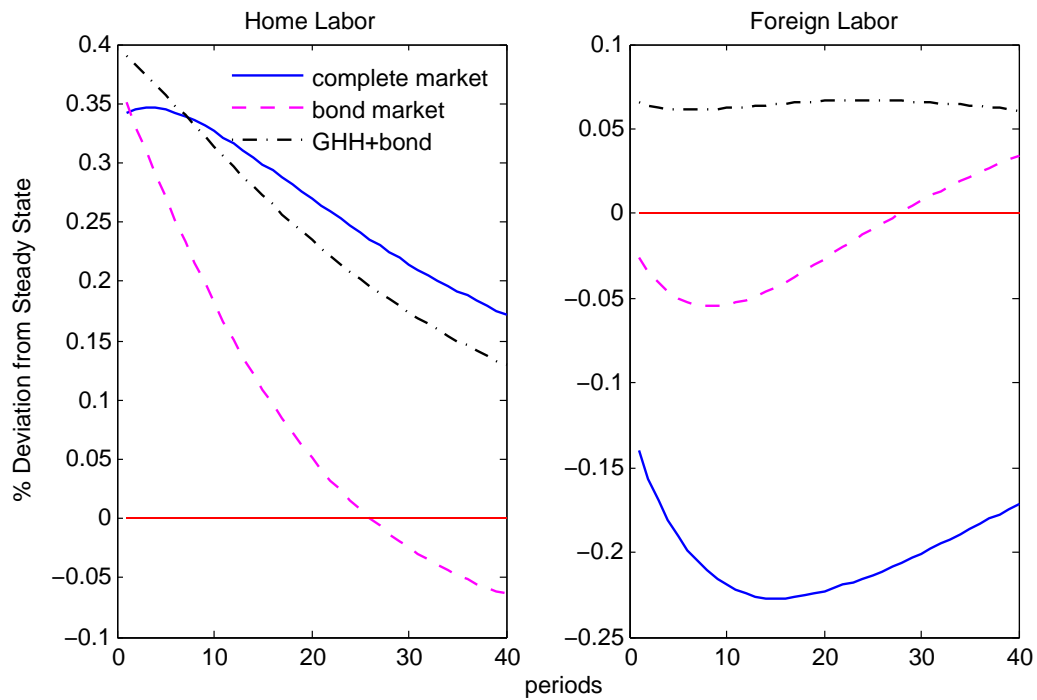


Figure 10: Impulse Responses to a Home Productivity Shock, Endogenous Labor





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