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Working paper

International Business Cycles with Heterogenous Sectors *

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Abstract

The 'quantity anomalies' that arise from standard international business cycle models are cross-country correlations in consumption being higher than output, and negative comovement in aggregate investment and employment. This paper shows that incorporating multiple sectors with heterogeneous factor intensities into an otherwise standard two-country stochastic growth model can resolve these anomalies. Endogenous *intratemporal* trade creates an additional channel for the propagation of productivity shocks across countries, competing with the standard, 'resource allocation effect'. Moreover, a country-specific technology shock can induce reallocation of resources both across industries and countries. These reallocations alter the composition of goods produced in countries over the business cycle, and can generate 'procyclical' and 'countercylical' sectors. An important prediction is that sectoral inputs and outputs tend to be more correlated across countries for more labor-intensive sectors. Predictions of sectoral dynamics is shown to be broadly consistent with the data.

JEL Classification: **F21, F32, F41**

Key Words: **International Business Cycles, Multiple Sectors, Factor Proportions**

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1 Introduction

Standard international business cycle models assume exogenously determined structures of trade. In these settings, some quantitative properties which are at odds with the data include cross-country correlations of consumption being much higher than those of output, and the negative comovement of investment and employment. The opposite is true in the data, and the term, 'quantity anomalies', arose to describe the main failings of standard two-country stochastic growth models (Backus Kehoe and Kydland (1993)).

The resolution of these anomalies proposed so far entails the assumption of endogenous incomplete asset markets featured in Kehoe and Perri (2001). In these settings, investment and employment can commove positively, while the gap between the output and consumption correlation is substantially reduced, although not reversed. Yet another discrepancy arises: net exports become procyclical, rather than countercyclical as in the data.

We show that the reliance of asset market frictions is not necessary to replicate the key features of international business cycles, and that standard complete markets models can still go a long way in resolving these anomalies. The key is to allow for endogenous trade dynamics. When there are multiple sectors, heterogeneous in factor intensities, a scope for intratemporal–commodity trade arises over the business cycle. When one country is hit by a positive labor productivity shock, it disproportionately expands its labor-intensive sectors, causing the world price of labor-intensive goods to fall and the price of capital-intensive goods to rise. The possibility of trade thus induces resource reallocation both across sectors and across countries, changing the composition of goods produced by each country. The shift in the composition of goods towards more capital-intensive industries abroad engenders a rise in investment demand, causing investment and output to comove positively across countries.

This trade-induced macroeconomic dynamics competes with the standard "resource allocation effect" whereby inputs are shifted towards the more productive economy. Since this is the only force present in the standard one-sector, or full specialization Armington model of Backus Kehoe and Kydland (1992), (1994), where trade is exogenously determined, investment and output are invariably negatively correlated across countries.[1] These negative correlations can be reversed if the composition effect dominates the resource allocation effect. We provide conditions under which one effect dominates the other and show that these conditions are met by the data.

[1] Baxter (1995) has written that "It has proved particularly difficult to write down plausibly-parameterized models which can generate positive comovement of labor and investment across countries. Thus a major challenge to the theory is to develop a model which can explain international comovement in labor intput and investment.

In the past, the investigation of international and domestic comovement in output and investment has been primarily at the aggregate level. Yet aggregate dynamics masks the heterogeneous behaviour of these very variables at the sectoral level, both domestically and across countries. Examining industry-level data in the U.S. and OECD countries reveals that cross-industry, and cross-country variations are substantial.[2] For instance, while most sectors are 'procyclical' in the US, in the sense that they expand along with aggregate GDP, other countries see substantial variation in the cyclicality of their domestic sectors. As shown in Table 1, more than half of Hungary's sectors experience a contraction when its output rises. Its manufacturing sector is strongly countercyclical, with a correlation with domestic GDP of -0.51, while its agriculture sector is strongly procyclical, with a correlation of 0.68. Similar patterns arise in many countries in the sample.

International correlations of output at the sectoral level display a similar degree of heterogeneity. Looking at this correlation between the U.S. and other OECD countries, at least one third of the sectors for all U.S.- OECD country pairs display negative comovement (Table 8). On the aggregate level, however, most countries' output comoves positively with that of the U.S, as documented first by Backus et al (1992) (henceforward, BKK).

In standard multiple sector models with homogeneous factor intensities, a positive, country-specific productivity shock causes a unilateral expansion of all sectors in that country, and a unliateral contraction of all sectors abroad. Resource reallocation across sectors is absent in these settings. This paper shows that it is possible to explain both the aggregate-level and sectoral-level dynamics within a country and across countries with country-specific technology shocks in a standard international business cycle framework with heteregeneous sectors. A sharp prediction arises: labor-intensive sectors' output are more correlated across countries than capital-intensive ones. This prediction is shown to be generally consistent with the data.

Broadly, this paper contributes to bridging the gap between trade and international macroeconomics. In standard macroeconomic frameworks, trade patterns are unaffected by the macro phenonemnon and aggregate feedback effects of trade patterns are shut down. The recognition that trade and specialization patterns need to be endogenized in these setups has lead to recent endeavors,[3] such as Ghironi and Melitz (2004), which incorporates a Melitz-model of trade with monopolistic competition and heterogeneous firms into a two-country, stochastic growth model and shows how persistent deviations from PPP may arise

[2]OECD countries include Austria, Belgium, Denmark, France, Germany, Italy, Luxembourg, Netherlands, Norway, Sweden, Switzerland, Canada, Japan, Finland, Greece, Portugal, Spain, Turkey, Australia, New Zealand, Korea, Czech Republic, Slovakia, Hungary and Poland.

[3]Kose and Yi (2003) points out: "In our view, the next step is to adopt a multi-sector structure in which specialization patterns are determined endogenously".

in a world of flexible prices. Kose and Yi (2003) examines whether vertical specialization can explain business cycle correlations across countries. The paper also demonstrates the need to closely examine sectoral level dynamics, and provides a theory that can replicate the main features of of international business cycle properties both on the aggregate level and on the sectoral level.

The paper is organized as follows. Section 2 describes the multiple-sector international business cycle framework. Section 3 presents the stochastic properties of a multi-sector fixed-labor economy and compare them with the data and those of the existing literature. Section 4 compares the case that incorporates endogenous labor in a multi-sector setting with the results from previous literatures. Section 5 reports sensitivity analysis, and Section 6 documents the cyclicality of prices on the sectoral level and the relationship between international correlations of sectoral output and factor intensities. Section 7 concludes.

2 The Model

2.1 Preferences and Technologies

Consider a two-country world, Home and Foreign, each characterized by a large number of identical, infinitely lived consumers. The countries produce the same type of intermediary goods $i = 1...m$, which are traded freely and costlessly, and are conveniently indexed by their labor intensity, $1 - \alpha_i > 1 - \alpha_j$ for $i > j$. 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 $s^t = (s_0, ...s_t)$ 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

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

where $c^j(s^t)$ denotes consumption per capita at time s^t in country j, $l^j(s^t)$ denotes labor, and β denotes the discount factor. The utility function for the consumer is assumed to be $U(c, l) = \frac{[c^{\mu}(1-l)^{1-\mu}]^{1-\sigma}}{1-\sigma}$.

There are two types of production technologies in each of these two economies. The first type employs capital and labor to produce an intermediate good i in country j:

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

Gross Value Added by Sector: Correlations with Domestic GDP			
Sectors	**U.S.**	**Hungary**	**Spain**
Agriculture Fishing and Forestry	0.53	0.68	-0.39
Mining	0.64	0.71	-0.39
Manufacturing	0.89	-0.51	0.82
Food Beverage and Tobacco	-0.14	-0.04	0.33
Textiles	0.72	-0.25	0.40
Leather	.	-0.45	-0.36
Wood	0.41	0.34	0.69
Pulp and Paper	0.70	0.14	0.65
Refined Fuel	-0.26	0.06	-0.29
Chemicals	-0.04	0.17	0.39
Plastic and Rubber	0.45	-0.22	-0.23
Non-metalic Minerals	0.56	-0.56	0.75
Metals	0.89	-0.04	0.90
Machinery	0.64	-0.37	0.51
Electrical	0.82	0.19	0.37
Transport Equipment	-0.13	-0.30	-0.23
Other Manufacturing	0.84	-0.40	0.67
Utilities	0.38	-0.10	-0.34
Construction	0.47	0.56	0.67
Wholesale and Retail Trade	0.00	0.15	0.70
Hotels and Restaurant	0.92	-0.49	0.70
Transport	0.92	-0.16	0.68
Finance	0.48	0.91	0.78
Real estate	0.87	0.00	0.92
Public Admin	-0.42	0.83	0.75
Education	-0.11	0.47	0.52
Health	-0.53	0.79	0.43
Social Services	0.14	-0.42	0.59

Table 1: Sectoral-level and aggregate output are taken from OECD *Annual National Accounts Detailed Table* from 1990:1-2008:4. The data statistics are Hodrick-Prescott-filtered with a smoothing parameter of $1,600$.

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, $l_i^j(s^t)$ is the aggregate input of labor employed in sector i, in country j. Production of intermediate goods is subject to a country-specific random shock $A^j(s^t)$, which follows an exogenous stochastic process.

Labor market clearing requires that at each date

$$\sum_i l_i^j(s^t) = l^j(s^t)$$

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

The second technology produces a final good by combining intermediate goods $Y_i^j(s^t)$ with an elasticity of substitution θ:

$$Y^j(s^t) = \left[\sum_{i=1}^{m} \gamma_i^{\frac{1}{\theta}} (Y_i^j(s^t))^{\frac{\theta-1}{\theta}}\right]^{\frac{\theta}{\theta-1}}$$

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 $x_i^j(s^t)$ is investment in country j in sector i.

$Y^j(s^t)$ is used for two purposes: consumption, $c^j(s^t)$ and investment, $x_i^j(s^t)$. Denoting $C^j(s^t)$ as the aggregate consumption in country j, the aggregate resource constraint requires world output to equal world consumption and investment

$$\sum_{j=H,F} Y^j(s^t) = \sum_{j=H,F} C^j(s^t) + \sum_{j=H,F}\sum_i x_i^j(s^t) \tag{1}$$

2.2 The Social Planner's Problem and Competitive Equilibrium

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 tood $P(s^t)$ to 1 so that

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

The allocation that solves the social planners' problem of maximizing the discounted utilities

$$\max \lambda^H \sum_{t=0}^{\infty} \sum_{s^t} \beta^t \pi(s^t) U(c^H(s^t), l^H(s^t)) + \lambda^F \sum_{t=0}^{\infty} \sum_{s^t} \beta^t \pi(s^t) U(c^F(s^t), l^F(s^t))$$

subject to the resource constraint Eq. 1 coincides with the competitive equilibrium when imposing that $\lambda^H = \lambda^F$, and the symmetry of shocks, utility functions, and production techniques.

Once this solution is characterized, the appropriate multipliers give the competitive prices. The relative price of the intermediate goods is

$$\frac{p_i(s^t)}{p_j(s^t)} = \left(\frac{\gamma_i Y_j^w(s^t)}{\gamma_j Y_i^w(s^t)} \right)^{\frac{1}{\theta}}. \tag{2}$$

The equilibrium we focus on is one in which countries diversify in production.[4].

2.3 The 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 equlization holds, the steady state is just the integrated equilirium parable. The allocation of labor and capital across sectors, in the case of $\theta = 1$, are such that

$$l_i^w = \frac{\gamma_i(1-\alpha_i)}{\sum_i \gamma_i(1-\alpha_i)} l^w \tag{3}$$

$$K_i^w = \frac{\gamma_i \alpha_i}{\sum_i \gamma_i(1-\alpha_i)} K^w \tag{4}$$

Prices and wages are independent of domestic factor endowments and is determined entirely by world endowments.

$$\frac{p_i}{p_k} \propto (\frac{K^w}{l^w})^{\alpha_k - \alpha_i} \tag{5}$$

$$w \propto (\frac{K^w}{l^w})^{\sum_i \alpha_i \gamma_i} \tag{6}$$

[4]A sufficient condition for non-specialization is $\epsilon_A^F(s^t) < l_1^H(s^{t-1})$, that the country-specific shock in F, be less than the labor allocated to the sector 1 (labor-intensive sector) in H in the previous period (Proof see Jin (2008))

Although the world as a whole is a standard stationary Ramsey economy with a well specified steady state, chacterized by a unique world capital to labor ratio, and consumption and labor are 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. However, the presence of adjustment costs pins down a unique path of capital, so that when initial conditions $k^j(s^0)$ are exogenously given, the transitional dynamics leads the system to a unique steady state.[5] In contrast to the Ramsey model, this economy features path dependence. We assume that countries are initially symmetric.

3 Fixed-Labor Case

3.1 Goods and Factor Prices

The impact behavior of goods and factor prices can be analyzed analytically in a two-sector case with Cobb-Douglas preferences ($\theta = 1$), and with exogenous labor ($\mu = 1$), shedding light on the channels through which aggregate shocks are transmitted across countries. Denoting ˆ variables as percentage changes, we have, for any country j and sector i,

$$\hat{w_i^j} = \hat{p}_i - \alpha_i \hat{\tilde{N}}_i^j$$

$$\hat{R_i^j} = \hat{p}_i + (1 - \alpha_i)\hat{\tilde{N}}_i^j$$

where $\tilde{N^j} \equiv A^j N_i^j$. A high ϵ_t^h, a technology boom in Home, causes a disproportionate expansion in labor-intensive sectors in country j. The increase in the world supply of labor-intensive goods depresses its relative price, and raises the relative price of capital-intensive goods. Foreign responds to the greater profitability of capital-intensive sectors by shifting resources there. Returns in the capital-intensive sector in Foreign rises both because of its higher commodity price, p_{2t}, and also because of the increase in labor employed in that sector, which raises the marginal product of capital. In contrast, the rate of return falls in the labor-intensive sector in Foreign. At Home, an increase in efficiency causes both sectors to expand, and a higher return to capital across all sectors. The ranking of changes in goods

[5] Jin (2009) and Cunat and Maffezzoli (2004) also use adjustment costs to pin down the path of captial in a world of factor price equalization.

and factor prices is:[6]

$$\hat{R}_2^h > \hat{R}_1^h > \hat{w^h} > \hat{p}_1 > 0 > \hat{p}_2$$

$$\hat{R}_1^f > \hat{p}_1 > 0 > \hat{p}_2 > \hat{R}_2^f$$

Home subsequently exports labor-intensive goods and Foreign, capital-intensive goods. Through the channel of commodity trade, a country-specific technology shock in one country engenders sectoral reallocation in the rest of the world. The structure of trade evolves endogenously over the business cycle and acts as an additional channel of propagation for shocks.

3.2 Calibration

To examine the aggregate impact of trade on macroeconomic variables, we calibrate a three-sector model, and compare the quantitative properties of our theoretical economies with those of the data, and with the benchmark world economy. To stay as close as possible to the benchmark one-sector framework, I take the specification of preferences and technology in Backus, Kehoe, and Kydland (1992) and Kehoe and Perri (2002). Standard parameters are given in Table 2. The main point of departure from these one-sector models is the calibration of factor intensities α_i, preference parameter γ_i, and the elasticity of substitutions θ. γ_i's are equal to the share of sector i in the world's total value added, in an integrated equilibrium. Estimates of factor intensity shares and γ_i's are provided in Cuñat and Maffezoli (2004). Using OECD Annual National Accounts Detailed Table, they aggregate the value of 28 sectors across 24 OECD countries, and calculate the share of each sector in total OECD value added. γ_i's are then calibrated to match these observed shares. Since $1 - \alpha_i$ is just the sector's labor share in value added, one can use data on compensations of employees to compute the sectoral labor share. Assuming that production technologies are identical across countries, the labor share across sectors is taken from U.S. data.[7] In aggregating 27 sectors into three large sectors,[8] I rank the sectors by their capital intensity and assume that the first 9 sectors are capital-intensive, and the last third the most labor-intensive. γ_1 is then chosen such that $\gamma_1 = \sum_{i=1}^{9} \gamma_i$, $\gamma_2 = \sum_{j=10}^{18} \gamma_j$. The capital shares α_k's are calibrated to match the weighted mean of the capital share of the 28 sectors, $s_k = \sum_{i=1}^{28} \gamma_i \alpha_i = 0.36$, and the weighted variance, $\sum_i \gamma_i(\alpha_i - s_k)^2$, which is 0.04 as measured from the 27-sectors data.[9]

[6]The impact on Foreign wages is ambiguous and depends on initial conditions: $\hat{w}_t^f < 0 \iff \frac{N_{1,t-1}^f}{N_{2,t-1}^f} < \frac{\gamma}{1-\gamma}\frac{\alpha_1}{\alpha_2}$.

[7]Internationally comparable estimates for all sectors and all countries are available only for 1995 and 1996. They assume that factor intensities have not changed significantly over time.

[8]I eliminate the 28th sector of 'Households' with a labor share of 1.

[9]We target the weighted mean and the weighted variance of the effective capital-intensity because the weighted mean partly determines the magnitude of the productivity shock, hence, the capacity for agents to

The resulting parametrization is given in Table 2. The elasticity of substitution between the goods, θ, is taken from Bernard, Eaton, Jensen, and Kortrum (2003), which calibrates it to fit U.S. plant and macro trade data, resulting in the value $\theta = 0.8$.

The specification of productivity shocks also follow Backus et al (1992) (BKK) and Kehoe and Perri (2002) (henceforth KP), where A_t^H, A_t^F follow a vector autoregressive (VAR) process of the form

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

The 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 sectors and across countries. Thus the shocks are stochastically related through the off diagnol element a_2, the spillover parameter, and the off-diagnoal elements of the covariance matrix V.

As pointed out in KP, Baxter and Crucini (1995) and Kollman (1996) use the production function and estimates of the inputs to form time series on A_t^j for the United States and some European countries, and find scant evidence for spillover, i.e. that a_2 is close to 0, but some evidence for substantial persistence, i.e. a_1 is large. In the baseline case we initially follow BKK in assuming that $a_1 = 0.906$, and follow KP in assuming no spillovers, $a_2 = 0$. In our sensitivity analyses, we explore the cases in which there is high persistence ($a_1 = 0.99$ and $a_2 = 0$), and with nonzero spillover ($a_2 = 0.85$, $a_2 = 0.15$), as well as the original estimates of BKK, ($a_2 = 0.906$ and $a_2 = 0.88$). Following KP, the covariance matrix is set such that $var(\epsilon_1) = var(\epsilon_2) = 0.007^2$ and $corr(\epsilon_1, \epsilon_2) = 0.25$, which are in line with all of the studies.

3.3 Findings

I compare the quantitative properties of a multi-sector theoretical world economy with differing capital intensities ($\alpha_i \neq \alpha_j$ for $i \neq j$), with a multi-sector model which features no differences in factor intensities ($\alpha_i = \alpha_j$ for all $i \neq j$), the one-sector benchmark model (BKK) with adjustment costs and without, and the data. We calculate the implied second moments of endogenous variables (percent deviations from steady state) using the frequency domain technique described in Uhlig [1999]. For consistency with BKK and KP, who focus on the high-frequency properties of business cycles in the United States and abroad,

save, and the weighted variance, which in this model, determines how strong specialization patterns will be following a productivity shock.

Experiments		Parameters	
Baseline Experiments			
	Preferences	$\beta = 0.99$, $\mu = 0.36$, $\sigma = 2$	$\theta = 0.8$, $\gamma_1 = 0.4$, $\gamma_2 = 0.27$, $\gamma_3 =$
	Technology	$\alpha_1 = 0.53$, $\alpha_2 = 0.34$, $\alpha_3 = 0.17$	$b = 1.8$, $\delta = 0.025$
	Productivity Shocks	$a_1 = 0.906$	$a_2 = 0$
		var(ϵ_1)= var(ϵ_2)=0.007^2	$corr(\epsilon_1, \epsilon_2) = 0.25$
Sensitivity Experiments			
	BKK	$a_1 = 0.906$	$a_2 = 0.088$
	High Persistence	$a_1 = 0.99$	$a_2 = 0$
	High Spillover	$a_1 = 0.85$	$a = 0.15$
	High Θ	$\theta = 3.8$	

Table 2: Parameters for various experiments

we report second moments of Hodrick-Prescott (HP)-filtered variables. Overall, the baseline multi-sector model improves upon the existing international business cycle models in matching the data in important dimensions, as shown in Table 3. In particular, output and investment comovement can become a natural feature of an endogenous trade model, in contrast to models with exogenous trade structures.

Comparing the standard one-sector BKK model with the data, a few major discrepancies of the theoretical economy emerge. Termed as the "two anomalies", the cross-country correlation in consumption is substantially higher than that of output (0.28 vs. -0.46), while the opposite is true in the data (0.32 vs. 0.51). So far, this "consumption-output anomaly" remains a stubborn counterfactual prediction in most models. Neither introducing trade costs into the BKK one-sector model, nor the KP model, or the sticky-price model of Chari, Kehoe, and McGrattan (2002), and the international trade and business cycle model with heterogeneous firms model of Ghironi and Melitz (2005) is able to fully resolve this anomaly. The second anomaly is that the cross-country correlations of investment and employment are negative in the model (-0.17 and -0.15, respectively), while these correlations are positive in the data (0.29 and 0.43, respectively).

Adding adjustment costs increases the cross correlation of investment and output although the correlation remains negative, (-0.76 and -0.85, respectively.) Net exports becomes procyclical rather than acyclical as in the absence of adjustment costs. As stated in BKK, the correlation of investment and output are robust to drastic changes in parameters, and therefore termed as 'anomalies'.

In contrast, in a multi-sector model both investment and output comove positively (0.91 and 0.99, respectively). The gap between consumption comovement and output comovement has effectively disappeared. The main discrepancy that remains is that the trade balance is procyclical (0.9), rather than countercyclical in the data (−0.36), for the reason that investment flows are reversed from Home to Foreign, and by a bit too much. The procyclicality of the trade balance is a feature of the benchmark model with adjustment costs, as well as in economies with endogenous borrowing constraints of KP. Finally, comparing the baseline multi-sector model which features differences in factor intensity with one which does not, where $\alpha_i = \alpha_j$ for all $i \neq j$, it is clear that it is not sufficient to have multiple goods alone–the negative correlation of investment and output remain. The reason is that only driving force propragating country-specific productivity shocks is the "resource allocation effect", as in the one sector models, and factors of production are shifted to the more productive economy.

Although aggregate output and investment comove positively across countries, a dispersion of international correlations arises on the sector level (Table 4). The correlation decreases unambiguously with the labor-intensity of the sector, causing the most labor-intensive sectors' output and investment to comove negatively across countries. Domestically, each sector's contribution to variations in aggregate output are different and depends on the factor intensity of the sector. For Home, labor-intensive sectors contribute more to movements in GDP, while the opposite is true in Foreign. The most labor intensive sector contributes to 43% of the variance in GDP, while the most capital-intensive sector contributes to about 26% of GDP. In Foreign, more labor-intensive sectors account for about −66% of variations in GDP, and capital-intensive sectors account for 108%.

3.4 Impulse Responses

To gain some intuition on the properties of the theoretical economy, we next examine the impulse responses of variables in the economy to a positive country-specific productivity shock to Home. Assume that both countries's productivity have been at the average (mean) level for the time up until period 0, while Home switches to a high productivity while Foreign remains the same. Each figure juxtaposes the response from the BKK one-sector model and the baseline multi-sector model. Figures 2- 6 plot the percentage changes in the variables responding to the productivity increase in Home.

The dynamics of the technology shock is displayed in Figure 1, which increases by about 1.5% and then slowly decreases back to its mean. The productivity of the Foreign country remains the same as there are no spillovers ($a_2 = 0$). In the Home country in both cases output rises, and by about 1.2% and 1.15% in the one-sector and multi-sector case, in response to a 1.5% productivity shock. However, output in the Foreign country drops in the one-sector case, while in the multi-sector case it increases by a little less than 0.2%.

Business Cycle Statistics: Fixed-Labor					
Statistics	Data	Benchmark Multi-Sector ($\alpha_1 < \alpha_2$)	Multi-Sector ($\alpha_1 = \alpha_2$)	One Sector No Adj.Cost	One Sector Adj.Cost
Volatility					
% Standard Deviation					
GDP	1.72 (0.20)	1.06	1.15	1.43	1.38
Net Exports/GDP	0.15 (0.01)	0.02	0.04	3.77	1.06
% Standard Deviation Relative to GDP					
Consumption	0.79 (0.05)	0.89	0.59	0.25	0.3
Investment	3.24 (0.17)	3.10	3.10	7.12	3.2
Domestic Comovement					
Correlations with GDP					
Consumption	0.87 (0.03)	0.96	0.99	0.71	0.78
Investment	0.93 (0.02)	0.97	0.96	0.33	0.9
Net Exports/GDP	−0.36 (0.09)	0.99	0.95	0.09	0.13
International Correlations					
Home and Foreign GDP	0.51 (0.13)	0.98	−0.69	−0.97	−0.85
Home and Foreign Consumption	0.32 (0.17)	1	1	1	1
Home and Foreign Investment	0.29 (0.17)	0.97	−0.97	−0.91	−0.76

Table 3: *Note*: The statistics in the first 9 rows of the data column are given by Kehoe and Perri (2002), and are calculated from U.S. quarterly time series, $1970:1-1998:4$. The statistics in the last four rows of the data are calculated from U.S. variables and an aggregate of 15 European countries. The data statistics are GMM estimates of the moments based on logged (except for Net Exports) and Hodrick-Prescott-filtered data with a smoothing parameter of $1,600$. The numbers in parentheses are standard errors. The model statistics are logged and HP-filtered as the data series.

Business Cycle Statistics: Sectoral Level			
Statistics	Sector 1 ($\alpha_1 = 0.53$)	Sector 2 ($\alpha_2 = 0.34$)	Sector 3 ($\alpha_3 = 0.17$)
Domestic Variance Contribution			
Home	0.26	0.31	0.43
Foreign	1.08	0.58	-0.66
International Correlations			
Output	1	0.97	-0.98
Investment	0.99	0.97	-0.86

Table 4: The contribution of sector i's output to the variance of GDP is calculated as $cov(Y_i^j, Y^j)/var(Y^j)$, where $\sum_i cov(Y_i^j, Y^j)/var(Y^j) = 1$.

As a result of complete markets, risk-sharing leads foreign consumption to rise along with

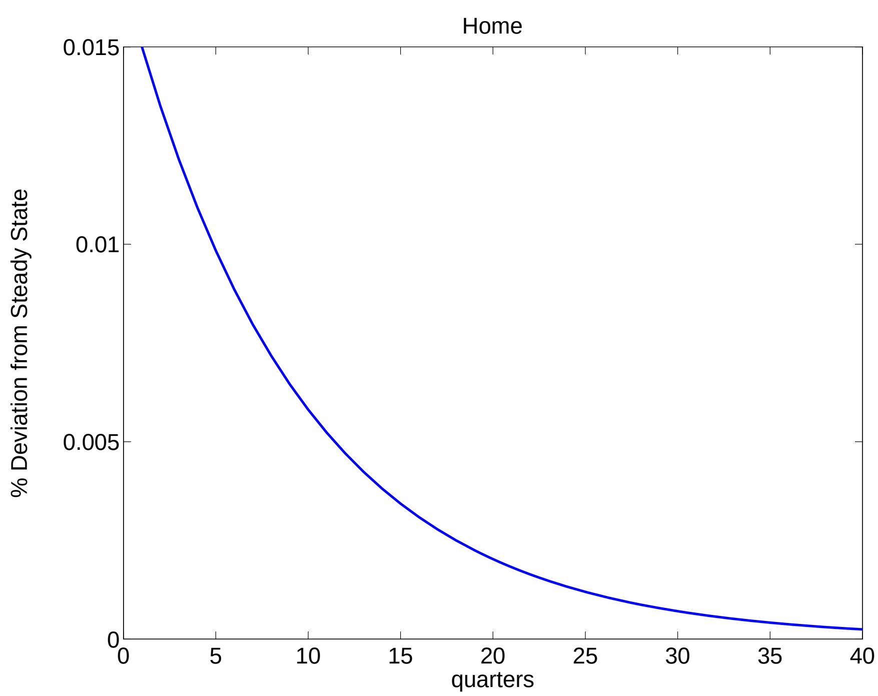


Figure 1: Productivity Shock at Home.

Home's consumption, in both the one-sector and the multi-sector case. In both economies, a Home productivity increase leads to a rise in Home's investment, by 3.4% in the one-sector case and by 2.8% in the multi-sector case. A key point of departure is the behavior of investment dynamics in Foreign—investment rises by more than 1% in the multi-sector case, in contrast to an initial fall of less than 1% in the one-sector case.

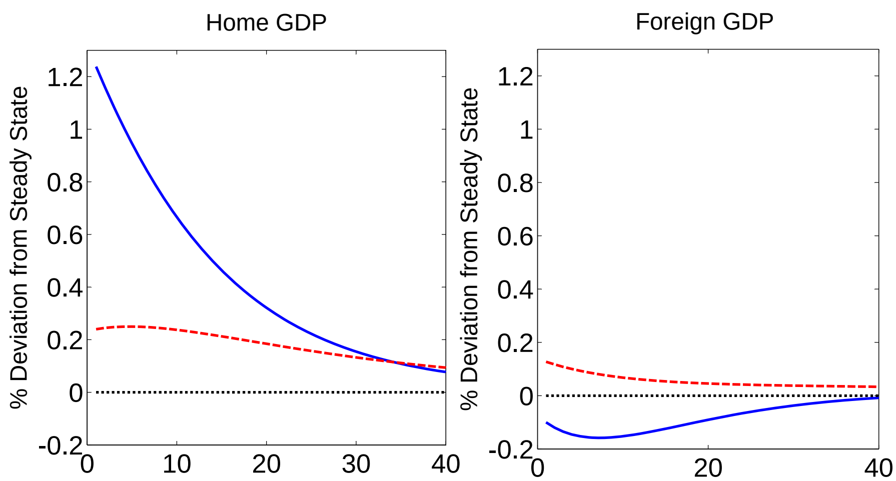


Figure 2: Impulse Responses of Output to a Home Productivity Shock. Solid line represents the response in the one sector case, and dashed line represents that of the multi-sector case.

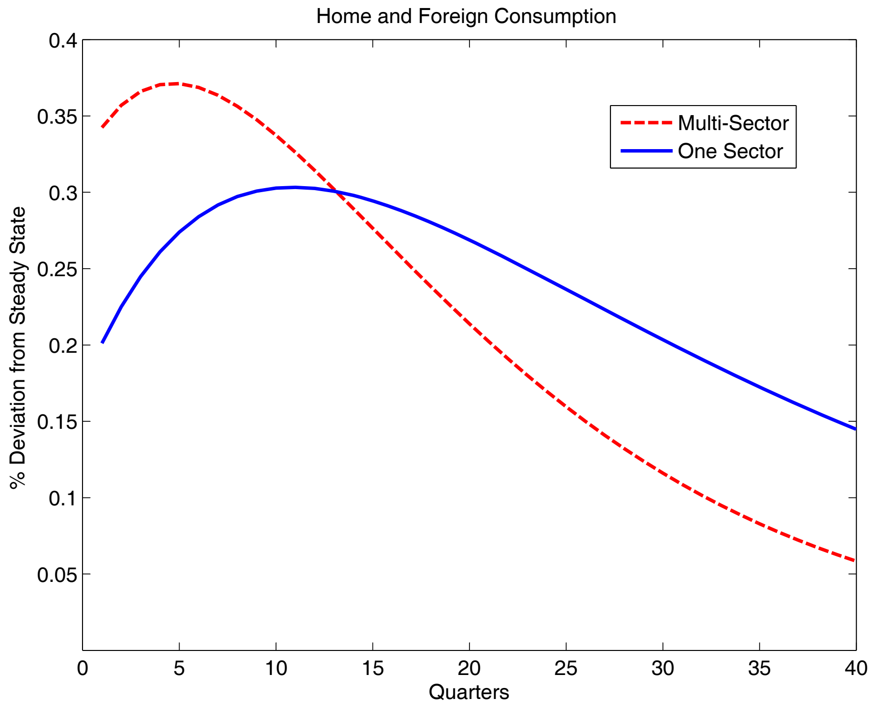


Figure 3: Impulse Responses of Output to a Home Productivity Shock. Solid line represents the response in the one sector case, and dashed line represents that of the multi-sector case.

On the sectoral level, the behavior of inputs and outputs vary substantially across countries. As seen from Figure 7, labor is shifted away from capital-intensive sectors (sectors 1 and 2) towards the most labor-intensive sector (sector 3) in Home, while the opposite occurs in Foreign. Investments on the sectoral level increases unilaterally in Home, while they follow the same pattern as employment in Foreign. This leads to a the largest increase in output in the most labor-intensive sector in Home (1.6%) and a contraction in Foreign (−0.6%). Labor-intensive sectors become Foreign's 'countercyclical' sector and capital-intensive ones, its 'procyclical' sector.

The intuition of these results is that, in the one-sector economy, resources are shifted to Home, which is more productive in both capital and labor. The capital stock increases in Home both because of higher domestic savings and also from investment flowing in from abroad. The net inflow of investment leads to an initial trade deficit in Home. As a result of perfect risk sharing, the increased output in Home causes consumption to rise also in Foreign. Overall, the shifting of resources towards the more productive Home economy causes a negative correlation of investments and outputs across countries.

In the multi-sector model, commodity trade acts as an additional channel of the trans-

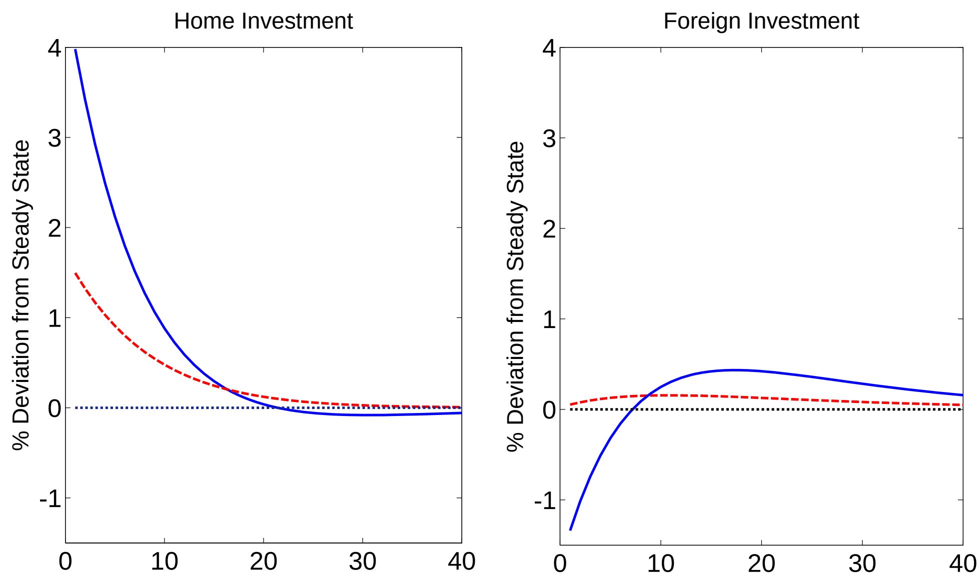


Figure 4: Impulse responses of investment to a Home productivity shock.

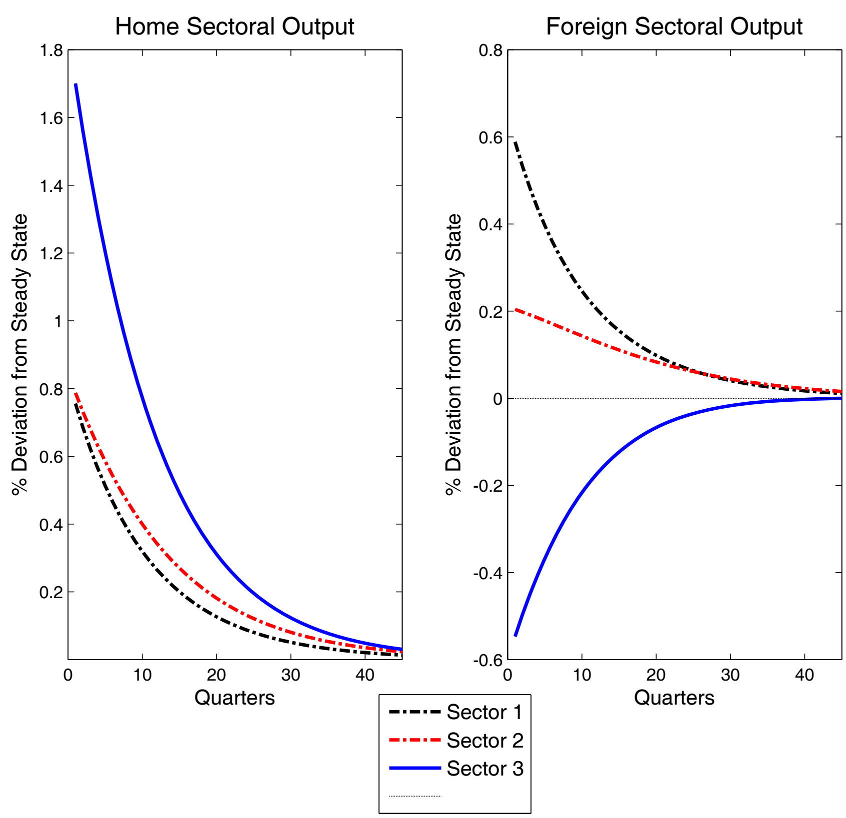


Figure 5: Impulse responses of sectoral output to a Home productivity shock.

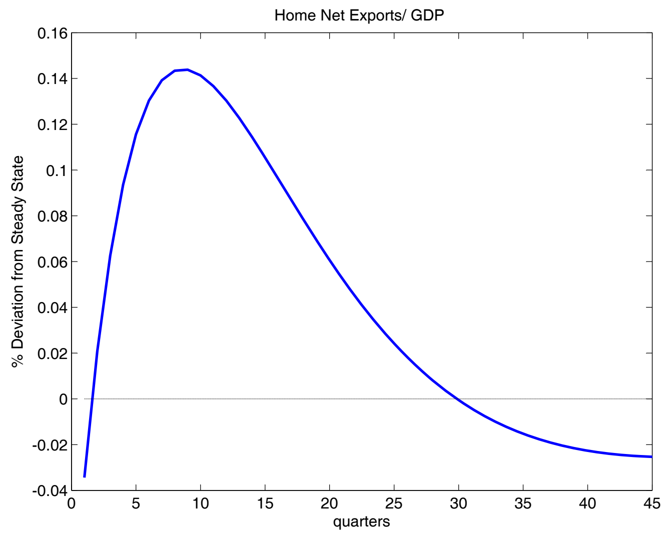


Figure 6: Impulse responses of Investment to a Home productivity shock.

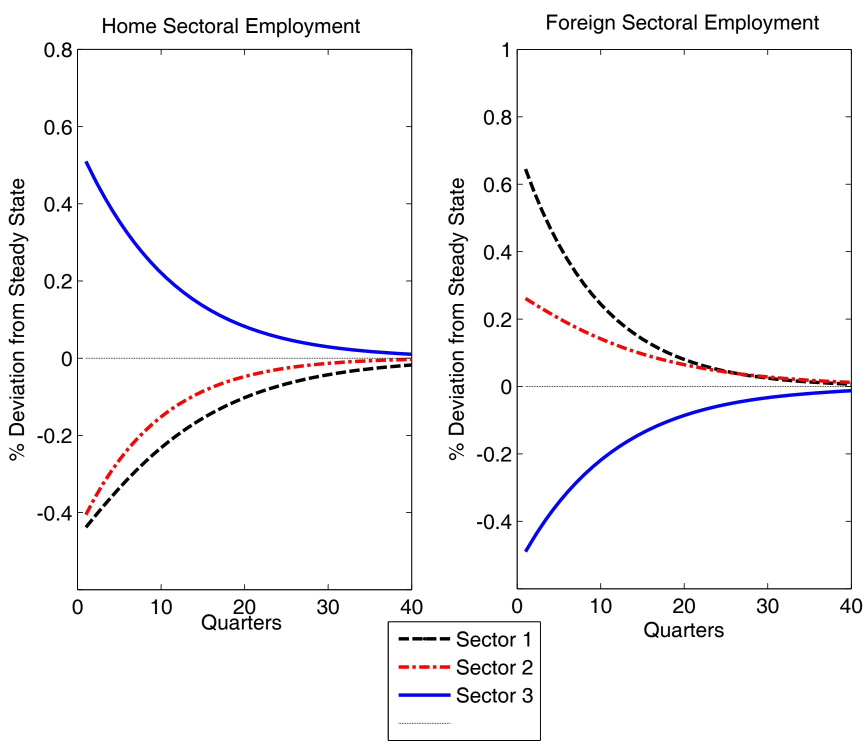


Figure 7: Impulse responses of sectoral employment to a Home productivity shock.

mission of shocks. A positive shock to Home's labor productivity causes a more than proportional expansion of its labor-intensive sectors. The increase in the world supply of the labor-intensive good bids up the relative price of the capital-intensive good, causing Foreign to shift resources (both capital and labor) to its capital-intensive sector. Consequently, Foreign becomes a net exporter of capital-intensive goods and Home a net exporter of labor-intensive goods. The increase in the demand for capital in Foreign, in order to increase its production in capital-intensive goods, leads Home to initially finance Foreign's investment. Investment rises in both countries.

Essentially two forces are at work in determining how resources are allocated across countries. First is the standard effect, whereby resources are shifted towards the more productive economy (investment flows towards Home). The second force is induced by trade, which causes a shift in the composition of production across countries, and causes investment to flow towards the country that increases its production of capital-intensive goods. The presence of the trade channel of adjustment reduces the extent to which the positive shock is accrued to Home alone, and the effect of the shock on output and investment is dampened. If the composition effect dominates, on net investment resources flows towards Foreign, and business cycles comove across countries.

Under what condition does one effect dominate the other? The intution is that if sectors are sufficiently different so that the change in the composition of goods across countries are pronounced enough, the trade-induced composition effect will dominate. As the sectors become more and more similar, the "resource allocation effect" dominates, and we are effectively back at the one-sector model when the factor intensity differences approach 0. How different do factor intensities have to be in order for the composition effect to dominate? A statistic to measure the dispersion in factor intensity is the weighted variance of the share of capital, $\sum_i \gamma_i(\alpha_i - \sum_i \alpha_i\gamma_i)^2$. The experiment that holds fixed the weighted mean $\sum_i \alpha_i\gamma_i$ to be 0.36, while varying the weighted variance, shows that Foreign's investment rises above a cutoff-weighted-variance of 0.02 (Figure 8). As sectors become more and more similar, Foreign's investment starts to fall. In the data, the weighted variance is about 0.04, above the cutoff point necessary for the composition effect to dominate.

4 Endogenous Labor Case

Next we examine how adding endogenous labor changes the results on the aggregate and sectoral level. Results are displayed in Table 6. A key determinant of the behavior of labor is the elasticity of substitution between the two goods θ, which governs the behavior of wages.

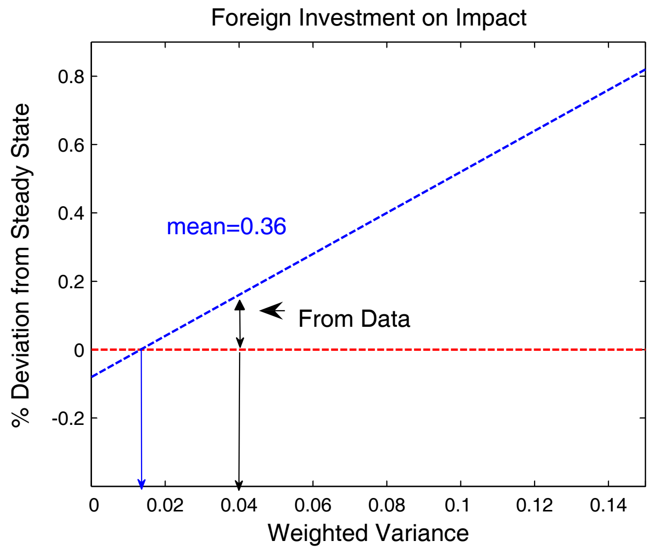


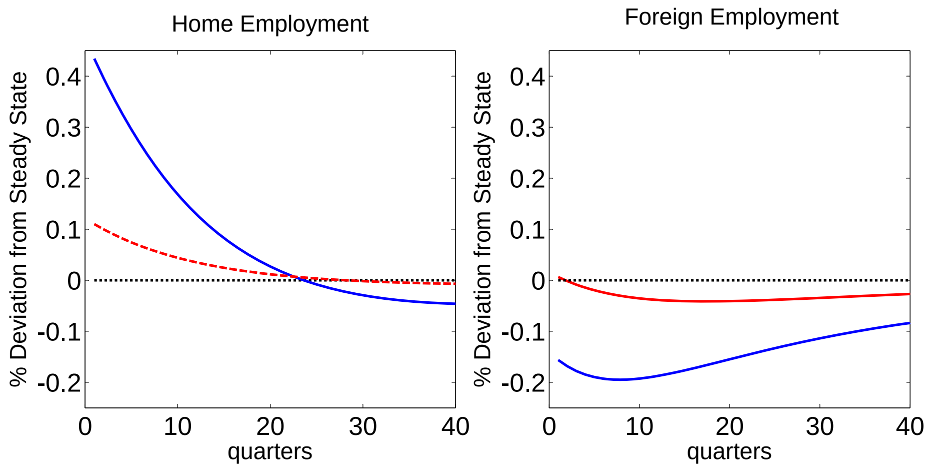
Figure 8: Foreign's response to a Home productivity shock in a multi-sector model. The weighted mean $\sum_i \alpha_i \gamma_i$ is held constant at 0.36, while choosing α_i's and γ_i's to vary the weighted variance $\sum_i \gamma_i(\alpha_i - \sum_i \alpha_i \gamma_i)^2$.

Real wages are determined by two components, the relative price of the two goods, and the marginal product of labor. The rise in the price of the capital-intensive good tends to increase real wages in Foreign, while the shift towards the more labor-intensive sector which causes a fall in the demand for labor in Foreign tends to reduce real wages. The composition effect is stronger the smaller the elasticity of substitution, θ, and the larger the increase in the relative price of capital-intensive goods. The price effect dominates for $\theta = 0.8$, causing wages to rise in Foreign, and therefore Foreign employment. As θ approaches infinity, the goods become perfect substitutes, and the behavior of employment is close to that in a one sector case. When these goods are highly complementary, an increase in the consumption of the labor-intensive good (as a result of the fall in its relative price) brings about greater demand for consumption of the capital-intensive good, in which case wages are bid up to induce the Foreign country to increase its production.

Aggregate labor rises in both countries, although the behavior of employment at the sector level differs dramatically both within countries and across countries. In Home, although labor is more productive across all sectors, employment only rises in labor-intensive sectors. The opposite is true for the Foreign country, which sees a rise in labor in capital-intensive sectors and fall in employment in labor-intensive sectors.

Aggregate investment and output do not change by much with the addition of endogenous labor. Output and investment remain to be positively correlated (0.99 and 0.27, respectively). The trade balance is now strongly countercyclical, with a correlation of -0.9

with domestic output.



5 Sensitivity Analysis

Table 5 reports the results of a sensitivity analysis on different parameters. Following BKK (1992), I examine the case in which there is *high spillover* (increasing a_2 from 0 to 0.15) and *high persistence* (increase a_1 from 0.9 to 0.99). The *high spillover* case changes very little from the baseline multi-sector results. In the spillover case, consumption is more correlated across countries than in the baseline case. The reason is that Foreign consumers, in observing an increase in producitivity in Home, increases their consumption in anticipation of the increase in future output due to the spillover.

In the *high persistence* case, the positive comovement of inputs and outputs across countries are dramatically reduced (and can become negative). The reason is that the more persistent is the shock, the smaller the savings incentive of agents relative to its demand for investment. A reduction in the supply of savings at Home reduces the ability to export investment to Foreign. Investment therefore falls in Foreign.

The elasticity of substitution between the two goods plays a crucial role in determining the correlation of employment across countries. In the case of high θ (a low elasticity), wages tend to fall in Foreign, and employment is negatively correlated across countries. Investment

Table 5: Business Cycle Statistics: Endogenous Labor Case

Statistics	Data	Baseline Multi-Sector ($\alpha_1 < \alpha_2$)	Multi-Sector ($\alpha_1 = \alpha_2$)	One Sector	KP
Volatility					
% Standard Deviation					
GDP	1.72	1.05	1.15	1.37	1.33
	(0.20)				
Net Exports/GDP	0.15	0.02	0.04	0.04	0.06
	(0.01)				
% Standard Deviation Relative to GDP					
Consumption	0.79	0.89	0.59	0.35	0.28
	(0.05)				
Investment	3.24	3.65	3.10	3.20	3.04
	(0.17)				
Employment	0.63	0.83	0.46	0.35	0.50
Domestic Comovement					
Correlations with GDP					
Consumption	0.87	0.99	0.99	0.98	0.93
	(0.03)				
Investment	0.93	0.96	0.96	0.98	0.99
	(0.02)				
Employment	0.86	0.98	0.99	0.99	0.99
	(0.03)				
Net Exports/GDP	−0.36	−0.89	−0.78	−0.35	0.27
	(0.09)				
International Correlations					
Home and Foreign GDP	0.51	0.98	−0.69	−0.84	0.25
	(0.13)				
Home and Foreign Consumption	0.32 (0.17)	0.89	0.99	0.99	0.29
Home and Foreign Investment	0.29 (0.17)	0.29	−0.97	−0.96	0.33
Home and Foreign Employment	0.43 (0.11)	0.69	−0.83	−0.91	0.23

The statistics in the first 9 rows of the data column are given by Kehoe and Perri (2002), and are calculated from U.S. quarterly time series, 1970 : 1 − 1998 : 4. The statistics in the last four rows of the data are calculated from U.S.l variables and an aggregate of 15 European countries. The data statistics are GMM estimates of the moments based on logged (except for Net Exports) and Hodrick-Prescott-filtered data with a smoothing parameter of 1,600. The numbers in parentheses are standard errors. The model statistics are logged and HP-filtered as the data series.

remains to comove positively across countries, although the fall in labor in Foreign dominates in exerting downward pressure on Foreign output.

6 Cyclicality of Sectoral Prices and International Correlations of Sectoral Output

The context in which the composition effect allows aggregate inputs and outputs to comove across countries is one in which labor-intensive sector prices falls and capital-intensive sector prices rise over the business cycle. Very little is known about the cyclicality of sectoral prices along the dimension of factor intensities. To investigate this, we take quarterly U.S. producer price data from the BLS, and compute the correlation of each sector's prices with U.S.'s GDP.[10] As shown in Table 7, certain sectors' prices are procyclical while others are countercyclical. Overall, labor-intensive sectors are associated with a greater fall in prices than capital-intensive sectors.

Next we examine international correlations of output on the sectoral level, comparing the U.S. against other OECD countries. First, from Table 6, it is clear that although aggregate output comoves positively with most other OECD countries, there is substantial variation in the comovement of output on the sectoral level. At least one third of sectoral outputs are negatively correlated with those of the U.S., in most countries. To examine whether there is a systematic difference between more capital vs. more labor-intensive sectors, we examine the correlation between the labor share of the sector with its cross-country output correlation. Theory predicts that the sign should be negative, in other words, that labor-intensive outputs should be less correlated than capital-intensive ones, since certain countries (those without the productivity shock) experience contractions of labor-intensive sectors and expansions of capital-intensive ones. The sign is right for 12 out of 21 country-pairs.

7 Conclusion

This paper develops a two-country, stochastic, general equilibrium business cycle model with endogenous trade dynamics. The existence of multiple sectors, each with differing factor intensity of production, generates intratemporal commodity trade in response to aggregate productivity shocks. Trade dynamics feedback onto the maro-economy: as the price of capital-intensive goods rises over the business cycle, the foreign country shifts resources

[10] Quarterly data for prices at the sectoral level is only available for the U.S., and not for OECD countries, the reason for which U.S prices are taken as a substitute for a measure of world producer prices.

Sensitivity Analysis					
		Multi-Sector			
Statistics	Data	Baseline	High Persistence	High Spillover	High θ
Volatility					
% Standard Deviation					
GDP	1.72	1.05	1.06	1.05	1.14
	(0.20)				
Net Exports/GDP	0.15	0.02	0.02	0.01	0.02
	(0.01)				
% Standard Deviation Relative to GDP					
Consumption	0.79	0.89	0.86	0.80	0.76
	(0.05)				
Investment	3.24	3.65	3.76	3.06	1.12
	(0.17)				
Employment	0.63	0.83	0.61	0.71	0.64
Domestic Comovement					
Correlations with GDP					
Consumption	0.87	0.99	0.99	0.99	0.99
	(0.03)				
Investment	0.93	0.96	0.95	0.97	0.99
	(0.02)				
Employment	0.86	0.98	0.99	0.99	0.99
	(0.03)				
Net Exports/GDP	−0.36	−0.89	−0.80	−0.89	0.97
	(0.09)				
International Correlations					
Home and Foreign GDP	0.51	0.98	0.86	0.99	−0.99
	(0.13)				
Home and Foreign Consumption	0.32 (0.17)	0.89	0.98	0.95	0.8
Home and Foreign Investment	0.29 (0.17)	0.29	−0.95	0.50	0.52
Home and Foreign Employment	0.43 (0.11)	0.69	−0.58	0.37	−0.99

Table 6: *Note*: The statistics in the first 9 rows of the data column are given by Kehoe and Perri (2003), and are calculated from U.S. quarterly time series, 1970 : 1 − 1998 : 4. The statistics in the last four rows of the data are calculated from U.S. variables and an aggregate of 15 European countries. The data statistics are GMM estimates fo the moments based on logged (except for Net Exports) and Hodrick-Prescott-filtered data with a smoothing parameter of 1, 600. The numbers in parentheses are standard errors. The model statistics are logged and HP-filtered as the data series.

Correlation of Sectoral Producer Prices and Domestic GDP in the U.S.		
Sectors	**Corr(p_i, Y)**	**Labor Share**
OilAndGas	0.05	0.47
Mining	-0.61	0.47
SportsMusicStores	0.39	0.55
Air Transportation	0.59	0.55
Rail Transportation	0.64	0.55
Water Transportation	0.08	0.55
Truck Transportation	0.55	0.55
Publishing	0.9	0.55
Broadcasting	-0.53	0.55
Transportation Equipment	0.61	0.57
Furniture	0.41	0.57
Finance	-0.61	0.57
Telecommunications	0.76	0.59
Computer Product	-0.38	0.60
Electrical Machinery	-0.39	0.60
Textiles	0.46	0.63
Primary Metals	-0.4	0.63
Fabricated Metal Product	0.7	0.63
Apparel	-0.18	0.66
Leather	0.23	0.66
Chemicals	0.74	0.67
Plastics Rubber Products	-0.01	0.67
Printing	0.3	0.68
Nonmetallic Mineral	-0.58	0.75
Mining Support	0.05	0.76
Food	-0.1	0.76
Beverage Tobacco	-0.68	0.76
Paper	0.17	0.77
Machinery	-0.43	0.78
PostalService	0.48	0.81
Correlation with Factor Intensity	-0.294	

Table 7: Quarterly producer price indices are taken from Bureau of Labor Statistics, covering the period of 1990:1-2008:4. All variables are logged and HP-filtered with a smoothing parameter of 1,600.

Correlations with US Output, by Sector							
Sector	**Labor Share** ($1-\alpha_i$)	**Austria**	**Belgium**	**Denmark**	**France**	**Germany**	**Italy**
Agriculture	(0.65)	0.264	0.238	0.044	0.071	0.137	0.274
Manufacturing	(0.35)	-0.427	0.738	0.156	0.097	0.259	-0.275
Food Bev Tobacco	(0.47)	0.044	0.180	0.327	-0.424	0.168	-0.193
Textiles	(0.78)	0.428	-0.525	-0.307	-0.442	0.265	-0.148
Wood	(0.69)	-0.640	-0.146	0.329	-0.328	0.173	0.061
Pulp and paper	(0.70)	0.104	0.262	0.616	-0.240	0.547	0.119
Refined fuel	(0.34)	-0.723	-0.192	.	-0.574	-0.536	-0.268
Chemicals	(0.44)	-0.163	0.152	-0.724	-0.647	-0.343	0.642
Plastic and Rubber	(0.77)	-0.050	0.560	0.149	0.159	0.040	0.182
Non-metalic minerals	(0.70)	-0.175	-0.264	0.224	-0.119	0.234	-0.140
Metals	(0.68)	-0.112	0.188	-0.031	0.384	0.233	-0.601
Machinery	(0.76)	0.250	0.644	0.160	0.551	0.655	0.783
Electrical	(0.63)	0.064	0.948	0.210	0.372	0.950	0.547
Transport Equipment	(0.78)	0.266	-0.163	0.396	-0.195	-0.158	0.036
Other Manufacturing	(0.66)	-0.058	0.042	0.417	-0.551	0.191	0.533
Utilities	(0.26)	-0.332	0.051	-0.009	0.206	0.449	0.077
Construction	(0.85)	-0.106	0.106	-0.154	-0.204	-0.585	0.116
Trade	(0.62)	0.096	-0.367	0.111	-0.027	0.447	0.177
Hotels and Restaurant	(0.62)	0.247	0.540	-0.252	-0.094	0.428	0.431
Transport	(0.59)	-0.206	0.197	0.165	-0.081	0.194	-0.067
Finance	(0.57)	0.468	0.253	-0.345	0.236	0.101	0.597
Real estate	(0.37)	0.168	0.547	0.519	0.597	-0.269	-0.245
Public Admin	(0.89)	-0.391	-0.106	-0.018	-0.658	0.011	0.364
Education	(0.95)	-0.002	-0.091	0.796	-0.334	-0.419	0.526
Health	(0.88)	0.566	-0.739	-0.256	0.252	0.076	-0.029
Social Services	(0.83)	0.127	-0.016	0.041	-0.588	-0.302	-0.124
Households	(1.00)	-0.445	-0.141	-0.176	-0.375	0.114	-0.311
Corr[$1-\alpha_i$,**corr**(y_c,y_{us})]		0.241	-0.354	0.042	-0.205	-0.087	0.121
		Luxembourg	**Netherlands**	**Norway**	**Sweden**	**Switzerland**	**Canada**
Agriculture	(0.65)	0.038	0.704	0.327	-0.612	0.577	0.640
Mining	(0.35)	0.099	-0.018	-0.526	-0.086	-0.018	-0.213
Food Bev Tobacco	(0.47)	-0.674	0.035	-0.008	0.322	0.024	0.331
Textiles	(0.78)	-0.046	-0.227	-0.189	-0.070	-0.083	0.244
Wood	(0.69)	0.072	0.211	0.070	0.327	-0.181	0.531
Pulp and paper	(0.70)	0.282	0.286	-0.022	0.307	-0.358	0.244
Refined fuel	(0.34)	.	0.129	.	-0.245	0.047	0.192
Chemicals	(0.44)	0.492	0.294	0.090	0.148	0.079	-0.020
Plastic and Rubber	(0.77)	-0.212	-0.135	-0.034	-0.364	-0.274	0.376
Non-metalic minerals	(0.70)	0.669	0.392	0.561	-0.159	0.360	-0.508
Metals	(0.68)	0.536	0.590	0.200	0.717	-0.090	0.588
Machinery	(0.76)	0.408	0.708	-0.379	0.122	0.481	0.754
Electrical	(0.63)	0.421	0.960	0.313	0.007	0.259	0.892
Transport Equipment	(0.78)	0.034	-0.106	0.458	-0.202	0.069	-0.023
Other Manufacturing	(0.66)	0.389	0.331	0.538	0.340	-0.381	0.288
Utilities	(0.26)	-0.056	-0.535	-0.729	-0.088	-0.498	0.232
Construction	(0.85)	-0.099	-0.260	-0.446	0.126	-0.398	0.451
Trade	(0.62)	0.646	0.073	-0.094	-0.639	0.048	0.260
Hotels and Restaurant	(0.62)	-0.275	0.311	0.286	0.307	-0.035	0.234
Transport	(0.59)	0.858	0.509	0.257	0.789	-0.446	0.697
Finance	(0.57)	0.847	-0.409	-0.025	0.579	0.434	0.602
Real estate	(0.37)	-0.188	0.567	0.565	0.721	0.530	0.653
Public Admin	(0.89)	0.542	0.531	-0.422	-0.024	0.044	0.342
Education	(0.95)	0.649	0.593	-0.292	-0.319	0.306	-0.566
Health	(0.88)	0.025	0.688	-0.211	-0.436	0.434	-0.428
Social Services	(0.83)	0.113	-0.482	0.633	-0.200	-0.133	-0.663
Households	(1.00)	0.372	0.253	-0.048	0.208	0.269	.
Corr[$1-\alpha_i$,**corr**(y_c,y_{us})]		0.193	0.177	0.013	-0.214	0.119	-0.237

Table 8: These statistics are calculated from OECD Annual National Accounts Detailed Tables covering 25 countries and 28 sectors. We omit Turkey, Australia, New Zealand, Poland and Turkey due to data availability. All variables are logged and HP-filtered with a smoothing parameter of 1,600.

Sector		Japan	Finland	Greece	Portugal	Spain	Korea
Agriculture	(0.65)	-0.072	-0.095	0.505	-0.023	-0.095	0.041
Mining	(0.35)	-0.313	0.221	-0.119	0.114	-0.276	0.013
Food Bev Tobacco	(0.47)	0.325	0.190	-0.118	-0.487	-0.404	0.265
Textiles	(0.78)	0.404	-0.208	0.068	-0.563	-0.369	-0.513
Leather	(0.55)	.	.	.	.	.	.
Wood	(0.69)	0.404	-0.324	0.457	-0.138	-0.088	-0.559
Pulp and paper	(0.70)	0.404	-0.360	-0.566	0.251	0.135	0.140
Refined fuel	(0.34)	-0.483	0.677	0.325	0.553	-0.398	0.489
Chemicals	(0.44)	0.531	-0.448	-0.351	0.570	-0.193	0.349
Plastic and Rubber	(0.77)	0.531	-0.021	0.440	-0.160	0.597	-0.337
Non-metalic minerals	(0.70)	0.484	0.375	-0.064	-0.049	0.377	-0.787
Metals	(0.68)	0.481	0.598	0.547	0.151	0.182	0.482
Machinery	(0.76)	0.850	0.475	0.579	0.038	0.169	0.300
Electrical	(0.63)	0.517	0.826	-0.558	0.365	0.504	0.579
Transport Equipment	(0.78)	0.505	0.524	0.771	0.253	0.571	-0.205
Other Manufacturing	(0.66)	0.800	0.299	0.542	-0.242	0.407	0.453
Utilities	(0.26)	-0.550	-0.498	-0.234	0.402	0.310	-0.491
Construction	(0.85)	0.557	-0.377	0.062	0.055	0.395	-0.431
Trade	(0.62)	0.660	0.400	-0.551	0.010	0.491	0.241
Hotels and Restaurant	(0.62)	.	-0.554	0.093	0.203	0.910	-0.898
Transport	(0.59)	-0.597	0.673	0.585	0.408	0.155	-0.624
Finance	(0.57)	0.112	0.134	0.272	0.211	0.673	-0.311
Real estate	(0.37)	-0.117	0.523	-0.747	0.560	0.424	-0.421
Public Admin	(0.89)	-0.080	0.572	-0.736	0.800	-0.581	-0.554
Education	(0.95)	.	-0.544	0.011	-0.050	0.490	0.203
Health	(0.88)	.	-0.119	0.136	-0.715	-0.261	-0.220
Social Services	(0.83)	0.088	-0.698	-0.385	-0.230	-0.550	-0.155
Households	(1.00)	.	0.511	-0.753	0.069	-0.251	-0.558
Corr$[1-\alpha_i$,**corr**$(y_c,y_{us})]$		0.554	-0.102	0.029	-0.376	-0.040	-0.197

		Czech Rep	Slovakia	Hungary
Agriculture	(0.65)	0.660	-0.528	0.202
Mining	(0.35)	0.001	0.013	0.281
Food Bev Tobacco	(0.47)	0.603	-0.074	0.086
Textiles	(0.78)	0.139	0.234	-0.938
Leather	(0.55)	.	.	.
Wood	(0.69)	0.169	0.038	-0.333
Pulp and paper	(0.70)	0.247	-0.429	-0.677
Refined fuel	(0.34)	-0.073	0.676	0.246
Chemicals	(0.44)	0.262	-0.026	0.106
Plastic and Rubber	(0.77)	0.205	0.376	0.320
Non-metalic minerals	(0.70)	0.226	0.474	-0.593
Metals	(0.68)	-0.095	-0.106	0.716
Machinery	(0.76)	0.830	0.350	-0.391
Electrical	(0.63)	0.508	0.492	-0.113
Transport Equipment	(0.78)	-0.142	0.053	0.454
Other Manufacturing	(0.66)	-0.004	-0.380	-0.793
Utilities	(0.26)	0.154	0.715	0.507
Construction	(0.85)	-0.249	-0.110	0.486
Trade	(0.62)	0.516	-0.317	0.060
Hotels and Restaurant	(0.62)	0.017	-0.236	-0.493
Transport	(0.59)	-0.862	-0.270	0.639
Finance	(0.57)	-0.576	-0.207	0.117
Real estate	(0.37)	0.528	0.015	-0.483
Public Admin	(0.89)	-0.526	-0.251	0.654
Education	(0.95)	-0.183	0.370	-0.195
Health	(0.88)	0.094	-0.312	0.544
Social Services	(0.83)	0.657	-0.193	-0.412
Households	(1.00)	0.107	.	.
Corr$[1-\alpha_i$,**corr**$(y_c,y_{us})]$		-0.111	-0.249	-0.079

from labor-intensive to capital-intensive sectors. The increase in the demand for capital in the capital-intensive sector abroad induces part of domestic investment to flow abroad. Investment and output rise globally.

This international business cycle model with trade dynamics is able to substantially improve upon existing models in matching key empirical features of the U.S. and international business cycle for reasonable assumptions about parameters and productivity. In particular, it is able to resolve both the consumption-output anomaly, and the investment-labor negative correlation anomaly, as well as generating positive GDP correlation across countries, while devoid of producing other counterfactual predictions.

Moreover, our model gives a rich set of predictions on the sectoral dynamics both within and across countries that are absent in standard models. The substantial heterogeneity in international correlations of output across sectors as revealed by industry-level data suggests that sectoral reallocation over the business cycle is a dimension worthy of further investigation. Future theories investigating the properties of international business cycles should give consistent accounts of sectoral-level dynamics, both within and across countries.

A Appendix

Sectoral-level output is taken from OECD *Annual National Accounts Detailed Tables* which covers 24 countries and 28 sectors. Data series for output, consumption, and employment for the U.S. and an aggregate of 15 European countries (Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, Sweden, and the United Kindom) are taken from OECD Main Economic Indicators, covering the period of the first quarter of 1970 through the fourth quarter of 2008. The variables of interest are gross domestic product, private final consumption expenditures, gross fixed capital formation (all real), and civilian employment.

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