# Intangible Investments and International Business Cycles[*]

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## Abstract

Intangible capital is an increasingly important factor of production in advanced economies. Governments in Europe and elsewhere promote investment in intangible assets. However, the potential role of intangibles for business cycles and the international transmission of shocks is not well understood. In this paper, we investigate the international business cycle effects of intangible capital. To this aim, we build an otherwise standard two-country real business cycle model augmented by a production sector for intangibles and allow for the non-rivalrous use of intangible capital in the production of final output goods and new intangibles. We find that a model including intangibles is associated with international co-movement of tangible investment, which is a feature observed in the data that many models fail to produce.

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# 1 Introduction

How does intangible capital impact on the international transmission of shocks? The answer to this question is not only of academic interest, but especially relevant against the background of a steadily increasing share of intangible capital in advanced economies. Policy makers in these countries often consider intangible investment as crucial for economic growth. In an attempt to analyze the impact of intangible capital on international business cycles, we extend a standard two country real business cycle model to include a production sector for intangible capital. Intangible capital mainly includes accumulated investments in research and development, market development, organization capital and training. Its immaterial characteristics give rise to the possibility that a firm uses the same stock of intangible capital simultaneously for different purposes. Following McGrattan and Prescott (2014), we assume that the stock of intangible capital can be used in the production of tangible output as well as to augment the stock of intangibles. While intangible capital can be used non-rivalrously in both sectors of production, we assume that it is non-tradable. Our modelling approach uses a broad definition of intangible investment that does not only include software and research and development expenditures - which are capitalized within the current System of National Accounts - but also spending on market development, organizational capital and managerial know-how. When intangibles are defined in such a broad way, businesses in some countries currently invest more in intangibles than they do in traditional fixed assets, according to Corrado, Haskel, Iommi and Jona-Lasinio (2013).

By including intangible production in our model, we can account for the finding that tangible investment tends to be positively correlated across countries, whereas a negative correlation is found by most theoretical models, including those with non-separable preferences (see e.g., Raffo (2010)). The extensive literature on the investment co-movement puzzle as well as on other international quantity and price puzzles was initiated by Backus, Kehoe and Kydland (1992) and includes, among others, Canova and Ubide (1998), Heathcote and Perri (2002), Kehoe and Perri (2002), Baxter and Farr (2005), Johri, Letendre and Luo (2011) and Corsetti, Dedola and Leduc (2014). The discrepancies between theory and data may be reduced when analyzing other countries or time periods (see e.g., Ambler, Cardia and Zimmermann (2004)). However, the general features and signs of correlations do no seem to change qualitatively. In standard models, a negative cross-correlation of investment arises because of incentives to use inputs where they are most productive. In our model, due to the two-sectoral structure with non-rivalrous use of

intangible capital, tangible resources can move across sectors to where they are most productive. This reduces incentives to relocate resources across countries.

This paper is organized as follows. Section 2 develops a two-country real business cycle model with two sectors that produce tangible and intangible goods. Section 3 describes the calibration of the parameters of the model. In Section 4, we investigate how the model reacts to a technology shock and how this shock transmits to the foreign economy. Finally, section 5 contains the conclusions.

## 2 Model

This section develops our model that comprises two sectors of production and two countries of equal size. The two-sector structure of production is similar as in the closed economy business cycle model in McGrattan and Prescott (2014).

### 2.1 Households

There are two countries - each one is populated by infinitely lived representative individuals. These individuals derive positive utility from consumption and experience disutility from working. To illustrate the basic features of a model with intangible production, we assume a standard classical utility function that is separable in consumption and labor: $U_t = \frac{c_t^{1-\sigma}}{1-\sigma} - \phi\frac{h_t^{\tau+1}}{1+\tau}$. $c_t$ is consumption, $h_t$ is hours worked and the parameters $\sigma$, $\tau$ and $\phi$ are all positive. Total hours worked $h_t$ is composed of hours worked in the tangible output sector $h_t^1$ and hours worked to produce intangible investment goods $h_t^2$. This utility function is maximized subject to the budget constraint:

$$
B_t^h + e_t B_t^f + P_t c_t + P_t x_{T,t} + Q_t x_{I,t} =
$$
$$
R_{t-1} B_{t-1}^h + e_t R_{t-1}^* B_{t-1}^f + P_t r_{T,t} k_{T,t} + P_t r_{I,t} k_{I,t} + P_t w_t h_t
$$
(1)

where $B_t^i$, for $i = h, f$, are nominal domestic and foreign bonds, and $e_t$ is the nominal exchange rate. $x_{T,t}$ and $k_{T,t}$ denote tangible investment and capital, while $x_{I,t}$ and $k_{I,t}$ stand for intangible investment and capital. $R_t$ is the nominal domestic interest rate on bonds and $R_t^*$ is the the nominal interest rate on foreign bonds. $P_t$ is the nominal price of consumption and $Q_t$ is the nominal price of intangible investment. The interest rate on tangible and intangible capital is denoted by $r_{T,t}$ and $r_{I,t}$ respectively; and the wage rate for labor is denoted by $w_t$. Capital depreciates at rates $\delta_T$ and $\delta_I$ for tangible and intangible capital, respectively. Adding convex adjustment costs for investments as it is

usually done in the international business cycle literature (see e.g., Raffo (2010)), the law of motions for tangible and intangible capital are:

$$k_{T,t+1} = x_{T,t} - \frac{\psi_{k_T}}{2} \left( \frac{x_{T,t}}{k_{T,t}} - \delta_T \right)^2 k_{T,t} + (1 - \delta_T)k_{T,t} \tag{2}$$

$$k_{I,t+1} = x_{I,t} - \frac{\psi_{k_I}}{2} \left( \frac{x_{I,t}}{k_{I,t}} - \delta_I \right)^2 k_{I,t} + (1 - \delta_I)k_{I,t} \tag{3}$$

Households choose $\{c_t, h_t, k_{T,t+1}, k_{I,t+1}, x_{T,t}, x_{I,t}, B_t^h, B_t^f\}$ to maximize utility subject to (1) - (3), which yields standard first-order conditions. The foreign economy has an identical economic structure and the optimality conditions are identical to those for the domestic economy. Subsequently, foreign variables will be denoted by '*'.

## 2.2 Firms

The tangible and intangible goods are produced by an intermediary that uses two constant returns to scale technologies. Firms produce tangible output $y_t$ using their tangible capital $k_{T,t}^1$, intangible capital $k_{I,t}$, and labor $h_t^1$. Firms produce intangible investment $x_{I,t}$ - such as research and development (R&D), brand development, organizational capital or training - using tangible capital $k_{T,t}^2$, intangible capital $k_{I,t}$ and labor $h_t^2$. The total stock of intangible capital $k_{I,t}$ is an input to both business sectors as in McGrattan and Prescott (2014). The intangible nature of these goods makes it possible to use intangible capital simultaneously for different purposes: it can be used both to deliver final goods and to develop new intangible capital. Following this reasoning, the production functions are given by:

$$y_t = A_t \left( k_{T,t}^1 \right)^\theta (k_{I,t})^\phi \left( h_t^1 \right)^{1-\theta-\phi} \tag{4}$$

$$x_{I,t} = A_t \left( k_{T,t}^2 \right)^\theta (k_{I,t})^\phi \left( h_t^2 \right)^{1-\theta-\phi} \tag{5}$$

The output elasticity parameters $\theta$ and $\phi$ are assumed to be the same across the two production functions. We resist the temptation to vary them across sectors of production, because our focus in this paper is on understanding the general effects of a model showing this special two-sector production structure. In the basic setup presented here, we also

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assume a neutral technology shock that does not vary across different types of production. The neutral technology ($A_t$) shock follows an AR(1)-process of the type:

$$\log A_{t+1} = \rho_A \log A_t + (1 - \rho_A)\log A + \epsilon_{t+1}^A$$

$A$ denotes the steady-state level of technology. The retailer firm combines foreign and domestic tangible goods to produce a non-tradable final good. It determines its optimal production by maximizing its profit

$$\max_{y_t^h, y_t^f} P_t Y_t - P_{y,t} y_t^h - e_t P_{y,t}^* y_t^f$$

where $P_{y,t}$ and $P_{y,t}^*$ denote the price of the domestic and foreign good respectively, denominated in terms of the currency of the seller. The final good is given by the following CES function

$$Y_t = \left(\kappa^{1-\eta} y_t^{h\eta} + (1-\kappa)^{1-\eta} y_t^{f\eta}\right)^{\frac{1}{\eta}} \tag{6}$$

where $\kappa \in (0,1)$ and $\eta \in (-\infty, 1)$. Optimal behavior of the retailer yields the following demand for the domestic and foreign goods:

$$y_t^h = \left(\frac{P_{y,t}}{P_t}\right)^{\frac{1}{\eta-1}} \kappa Y_t \tag{7}$$

and

$$y_t^f = \left(\frac{e_t P_{y,t}^*}{P_t}\right)^{\frac{1}{\eta-1}} (1-\kappa) Y_t \tag{8}$$

Cost minimization by the intermediary is complicated by the fact that the firm uses two different production functions. Additionally, the same stock of intangible capital appears in both production functions. The cost minimization process by the intermediaries yields standard expressions for the returns to the inputs of production except for the return to intangible capital, which depends on production in both the final goods and the international production sector:

$$r_{I,t} = \frac{\phi m c_t^1 y_t + \phi m c_t^2 x_{I,t}}{k_{I,t}} \tag{9}$$

Note that $mc_t^1$ and $mc_t^2$ denote the marginal costs in the two sectors of production.

# 3 Choice of Parameter Values

Table 1 depicts the choice of the parameter values. The domestic and the foreign economy share the same parameter values. In our model, one period corresponds to one quarter. We roughly follow McGrattan and Prescott (2012) and set the tangible capital share $\theta$ to 0.2 and the share of intangible capital $\phi$ to 0.15. In a sensitivity analysis, we vary these values and set $\theta$ to 0.25 and $\phi$ to 0.1 to investigate whether the quanlitative features of our model change when production is less intensive in intangible capital. As a result, the labor income share in total output is 0.65, which corresponds to the parameter value usually chosen for the labor share in a conventional model with only tangible capital. The capital share in a simplified version of the model with only tangible capital is 0.35. Also, as in McGrattan and Prescott (2012), we set the depreciation rate of intangible capital equal to that for tangible capital. The value chosen is 0.025, which is a standard value in the real business cycle literature. Similar as for tangible investment, the depreciation rate for intangible investment may considerably vary across sub-categories such as organizational capital or research and development. One should also bear in mind that uncertainty as to the appropriate depreciation rate for intangible capital is fairly high. Therefore, we conduct a sensitivity analysis and set the depreciation rate for intangibles at 0.05. The elasticity of trade $\eta$ is 0.5 and the trade share $1 - \kappa$ is 0.15.[1] The standard deviation of the technology shocks is set to achieve the same volatility of output as observed in U.S. data. The technology shocks are persistent with moderate cross-country spillovers to obtain cross-country output correlations similar to those in the data. As is usually done in the literature, we set the parameters governing the capital adjustment costs to approximately match the standard deviation of the tangible investment relative to GDP in the data.

Table 1: Choice of Parameter Values

| Parameter | Value | Parameter | Value |
|-----------|-------|-----------|-------|
| $\beta$ | 0.990 | $\rho^A$ | 0.950 |
| $\sigma$ | 2.000 | $\delta_T$ | 0.025 |
| $\theta$ | 0.200 | $\delta_I$ | 0.025 |
| $\phi$ | 0.15 | $\kappa$ | 0.850 |
| $\tau$ | 1.000 | $\eta$ | 0.500 |

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[1]These values lie in the range of values commonly used in the literature.

# 4    Simulation Results

## 4.1    Impulse Response Function

In this subsection, we first compare a version of our model with standard separable preferences to an analogous standard model that only includes tangible capital. Figure 1 shows the effects of a neutral technology shock to both the tangible and intangible production sector for a baseline model without investment adjustment costs. Figure 2 illustrates the reactions for the standard model with only tangible capital and without intangible production. As is apparent, there are several differences between the two models. Most importantly, when intangible investment is included in the analysis, the rise in domestic tangible investment also leads to a considerable increase in foreign tangible investment. Such co-movement cannot be observed for the model including only tangible capital. In our model, the two-sector structure of production allows resources to move across sectors to where they are most productive. This dampens the relocation of resources across countries. For intangible capital, however, the increase in domestic production only leads to a small increase in foreign intangible production. Also, the trade balance shows a somewhat different reaction when an intangible production sector is included and immediately turns positive in this case.

Figure 1: Domestic Neutral Technology Shock (Model Including Intangible Production)
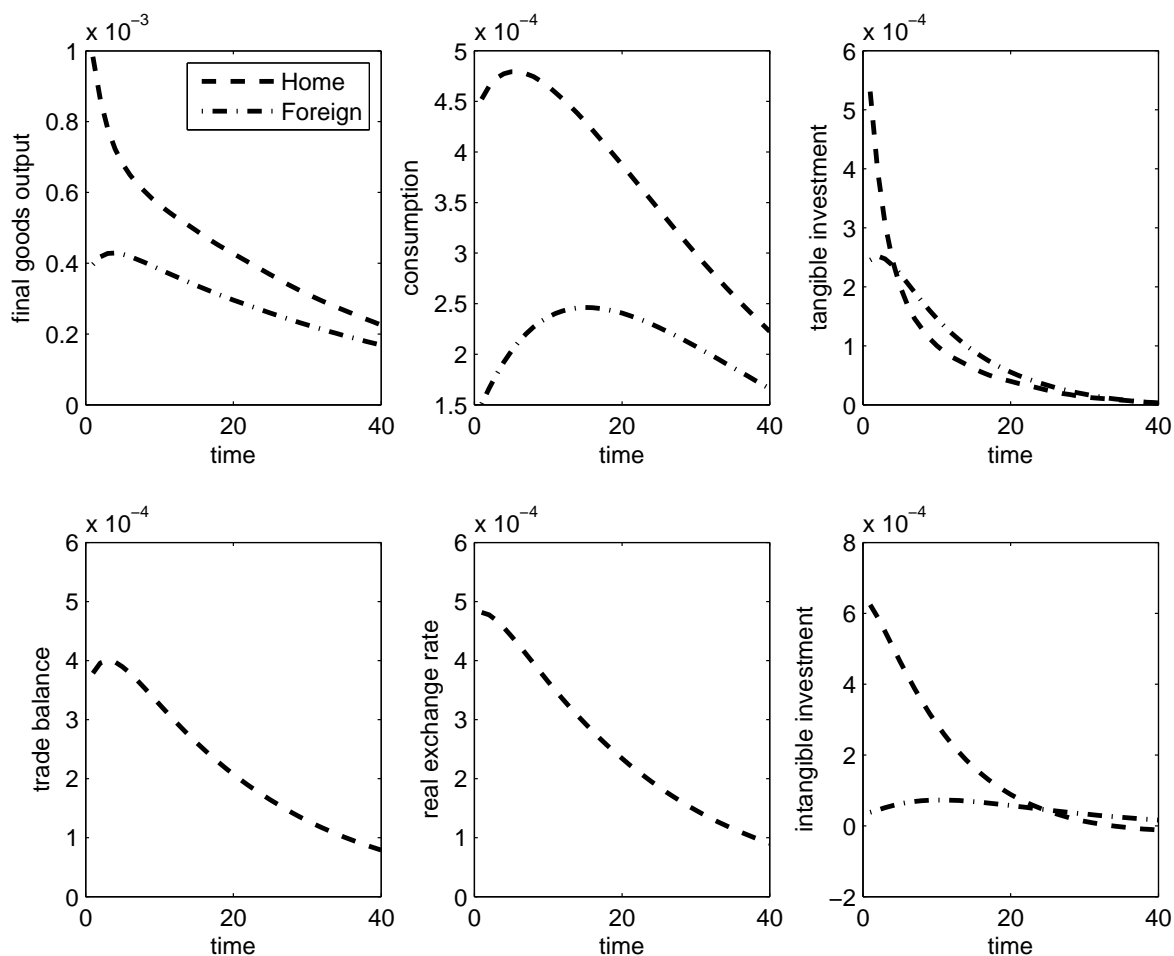


## 4.2   Quantitative Findings

This subsection presents Hodrick Prescott (HP)-filtered statistics for the data and various results of our model simulations for a neutral technology shock. To better match the quantitative predictions of the model with the data, we adopt the preference specification originally proposed by Greenwood, Hercowitz and Huffman (1988), where consumption and labor are not additively separable. This specification has been increasingly used in the international business cycle literature, mainly because it leads to the empirically observed co-movement of hours worked across countries. However, this specification does not lead to an international co-movement of tangible investment in conventional models without intangible capital. The specified utility function for an individual is then given

Figure 2: Domestic Neutral Technology Shock (Model Excluding Intangible Production)
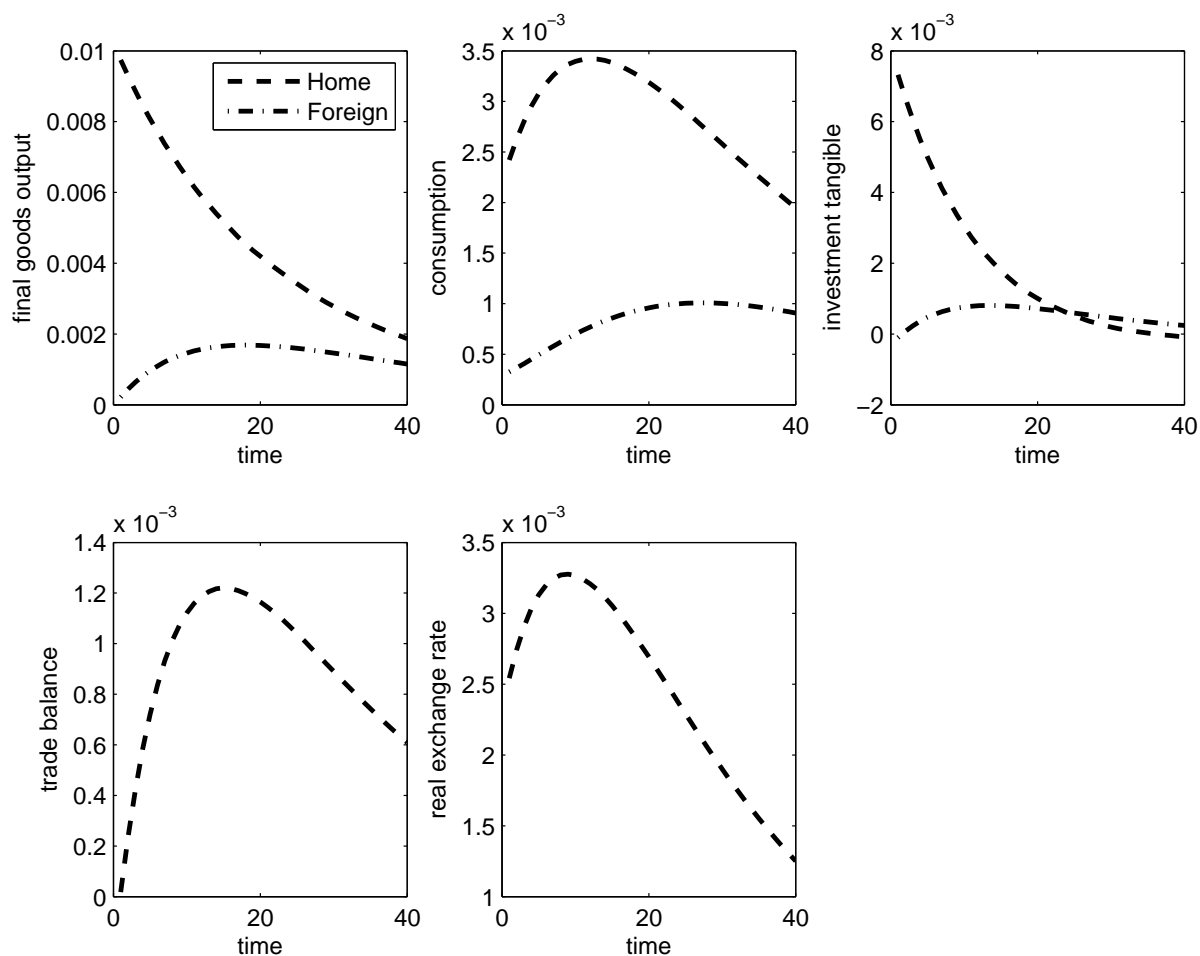


by: $E_0 \sum_{t=0}^{\infty} \beta^t \left( \frac{(c_t - \phi h_t^\tau)^{1-\sigma}}{1-\sigma} \right)$. Statistics for the data and the model simulations can be found in Tables 2-4. The first column refers to the findings of Raffo (2010) for the U.S. economy and an aggregate of foreign economies. The numbers are within the range of results found by previous studies. Real variables refer to seasonally adjusted annual rate (SAAR) series of chained dollars. In the literature, consumption and investment are defined as the sum of the respective private and public components. The trade balance is defined as the difference between real exports and real imports divided by GDP. The second column presents the results for a model with only tangible capital. The third column presents statistics for the baseline model with a neutral technology shock. The forth column presents results for a model where the income share of intangible production

is only 0.10 instead of 0.15 and the fifth column shows statistics for the case where the depreciation rate for intangibles is 0.05 instead of 0.025.

Overall, the model with intangible production performs quite well in reproducing the main features of the domestic business cycle, as can be seen in tables 2 and 3. An important difference emerges when considering the international cross-correlation of tangible investment. The model with intangible capital is more successful in generating a positive co-movement for investment, while a model that contains only tangible capital does not produce a positive co-movement despite the fact that the technology shocks are correlated across countries. In our model, tangible capital can move across sectors to where it is most productive because of the special two-sectoral structure of our model with intangible capital used in a nonrivalrous way in both sectors. This reduces incentives to relocate resources across countries. In our model, the cross-correlation of consumption is higher than output, while in the data for the US, the reverse is observed. Although this pattern is not observed in all countries (see Ambler et al. (2004)), it might be addressed, for instance using variable capacity utilization such as in Baxter and Farr (2005), to make it compatible with US data.

Table 2: Standard Deviations Relative to GDP

|  | US Data | baseline | only tangible | low intangible share | high depreciation |
|---|---|---|---|---|---|
| Consumption | 0.81 | 0.64 | 0.60 | 0.61 | 0.66 |
| Tangible investment | 2.87 | 2.87 | 2.87 | 2.87 | 2.87 |
| Hours worked | 0.87 | 0.60 | 0.59 | 0.59 | 0.61 |
| Trade Balance | 0.25 | 0.47 | 0.2 | 0.46 | 0.42 |

Table 3: Cross-Correlations

|  | US Data | baseline | only tangible | low intangible share | high depreciation |
|---|---|---|---|---|---|
| Consumption and GDP | 0.85 | 0.86 | 0.97 | 0.87 | 0.84 |
| Tangible Investment and GDP | 0.91 | 0.93 | 0.96 | 0.91 | 0.90 |
| Trade Balance and GDP | -0.43 | 0.31 | 0.19 | 0.12 | 0.26 |

Table 4: Cross-Correlations between Foreign and Domestic Variables

|  | US Data | baseline | only tangible | low intangible share | high depreciation |
|---|---|---|---|---|---|
| Consumption | 0.50 | 0.91 | 0.68 | 0.88 | 0.92 |
| GDP | 0.60 | 0.47 | 0.35 | 0.44 | 0.45 |
| Tangible Investment | 0.46 | 0.49 | 0.04 | 0.28 | 0.34 |

# 5 Conclusion

This paper finds that a two-country model with intangible production can account for the co-movement of tangible investment across countries. This feature is seen in the data, but cannot be replicated by conventional real business cycle models. The two-sectoral structure and the non-rivalrous nature of intangible capital reduce the need to move investments across countries, which leads to a positive correlation between domestic and foreign tangible investment. Future research should consider sector-specific productivity shocks and investigate whether this produces further business cycle statistics that are more in line with the data than those produced by conventional models. In addition, the continual improvement in the quality of the measurement of those intangibles that are not included in national accounts will open opportunities for further investigating the business cycle effects of intangible investment and for more precisely estimating the parameters used in business cycle models.

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