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Modeling News-Driven International Business Cycles

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Abstract

This paper reexamines the question of how to explain business cycle co-movements within and between countries. First, we present two simple theoretically flexible price models to illustrate how and why news shocks can generate robust positive co-movements in economic activity across countries. We also discuss under what conditions the multi-sector version of the model generates appropriate business cycle patterns within countries. Second, we develop a quantitative two-country multi-sector model that is capable of replicating many international business cycle facts. The model is a two-country extension of the closed economy model of Beaudry and Portier [2004], in which there are limited possibilities to reallocate factors between investment and consumption good sectors.

Key Words : Business Cycles, Expectations, International Fluctuations, News Shocks

JEL Classification : E32 – F41

Introduction

The macroeconomic literature often emphasizes the role of the expectations of investors in driving business cycles. These ideas go back at least to A.C. Pigou and J.M Keynes. One embodiment of this literature stresses the role of expectations regarding future productivity growth in creating fluctuations. This line of research is supported by empirical evidence suggesting that Total Factor Productivity improvements are reflected in stock prices fluctuations many quarters before they actually arise in measured TFP (see for example Beaudry and Portier [2005, 2006] and Haertel and Lucke [2007]). Theoretical and quantitative explanations of how news shocks affect economic activity have been investigated within a closed economy setups in a set of recent papers (Beaudry and Portier [2004], Christiano, Motto, and Rostagno [2005], Jaimovich and Rebelo [2006], Beaudry, Collard, and Portier [2006], Den Haan and Kaltenbrunner [2007]). In this paper, we examine the extent to which such changes in expectations, as captured by "news shocks", helps understanding international business cycle fluctuations.

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Business Cycles are known to display two important and quite distinctive features. The first one, that we label "National Business Cycles" (hereafter *NBC)* is the fact that macroeconomic aggregates (consumption, investment, output, worked hours) are positively correlated. The second one, that we label "International Business Cycles" (hereafter *IBC*) is the fact that these same aggregates are pairwise correlated across countries. These two set of facts are well documented in the literature (see for example Ambler, Cardia, and Zimmermann [2004]), and happen to be quite challenging to replicate for standard equilibrium macroeconomic theory. At first sight, the challenge seems easy to meet. As shown by Backus, Kehoe, and Kydland [1995] (hereafter BKK), a two country Real Business Cycle model in the tradition of Kydland and Prescott [1982] can display both NBC and IBC properties when perturbed by technological shocks. Note however that this result crucially relies on two assumptions: first that technological shocks are surprises and second that they are common across countries. These two assumptions, which are needed to generate NBC and IBC are questionable. First, technological improvements appear forecastable to a large extent, as Beaudry and Portier [2006] have shown that (permanent) technology improvements likely diffuse only slowly over time. Second, technological shocks are not common nor highly correlated across countries as shown in Ambler, Cardia, and Zimmermann [2004]. High correlation is needed in BKK type of models to replicate IBC facts, as purely local technological shocks lead to the reallocation of capital across countries and therefore generate negatively correlated cycles across countries.

As technology shocks appear insufficiently "global" to reproduce IBC facts, other shocks or market frictions seems to be needed for business cycles synchronization across countries to arise, as illustrated by Wen [2007]. We show in this paper that news shocks offer a driving force that can generate cross-country synchronization of activity even in a frictionless and flex-price economy. The key insight to understand the result is that, because news shocks are common knowledge and do not affect current fundamentals, they act as a common "demand" shock. In section 1 of this paper, we formally prove the synchronizing effect of news. In section 2, we propose a frictionless two-country quantitative model that builds on Beaudry and Portier [2004] closed economy model, and that is able to generate news-driven IBC. We also clarify why typical international RBC models fail generating news driven international business cycles. Section 3 concludes.

1 The Cross-Country Effects Of News Shocks

In this section, we study the consequences of country-specific news shock in multi-country models. Because news shocks materialize in the future in a single country but change current expectations in all countries, we show that they are a powerful source of synchronization between countries. We make this claim most clearly in a setup with instantaneous capital mobility, where the equilibrium allocation display perfect symmetry across country between the arrival of new information and the realization of the changes in fundamentals.

1.1 A One-Sector Setup With Instantaneous Capital Mobility

1.1.1 The Setup

Without loss of generality, the multi-country model we study is composed of two economies, A and B. Country A hosts a fraction $0 < \pi < 1$ of world population.

Both countries produce an homogenous final good, which can be consumed or augment the world stock of capital per capita K_t. This good is produced through the same constant returns to scale technology in both countries, $F(K_{J,t}, H_{J,t}; \theta_{J,t})$, with strictly positive marginal products. $H_{J,t}$ and $K_{J,t}$ respectively denote the labor and capital input per capita used in country J at date t. The technology index $\theta_{J,t}$ has a forecastable component and may have a non-forecastable one, but we need not explicit its stochastic process at this stage. To deliver our result in the simplest possible form, we assume that the world stock of capital per capita K_t is predetermined but that its geographical location is free, so that capital can be shipped away within a period from one country to the other. Denoting $K_{J,t}$ the per capita amount of capital allocated to country $J = A$ or B, the constraint on the allocation of capital writes

$$K_t \geq \pi\, K_{A,t} + (1-\pi)\, K_{B,t}.$$

There is one representative agent in each of the two-country, with the same period utility $U(C_{J,t}, 1 - H_{J,t})$ and positive first partial derivatives. The intertemporal utility is the discounted sum of period utilities, with discount factor β.

Goods are perfectly mobile across countries. Markets are complete and competitive, so that the competitive equilibrium is Pareto optimal. We therefore characterize equilibrium allocations by solving a social planner problem. The social planner chooses $C_{J,t}$, $H_{J,t}$, $K_{J,t}$, for $J = A, B$, and K_{t+1} in order to maximize

$$E_0 \sum_{t=0}^{+\infty} \beta^t \left[\pi\, U(C_{A,t}, 1 - H_{A,t}) + (1-\pi)\, U(C_{B,t}, 1 - H_{B,t})\right]$$

subject to, for all $t \geq 0$

$$\begin{cases} K_{t+1} \leq (1-\delta)\, K_t + \pi\,(F(K_{A,t}, H_{A,t}; \theta_{A,t}) - C_{A,t}) + (1-\pi)\,(F(K_{B,t}, H_{B,t}; \theta_{B,t}) - C_{B,t}) & (\lambda_t \geq 0) \\ K_t \geq \pi\, K_{A,t} + (1-\pi)\, K_{B,t} & (\nu_t \geq 0) \end{cases}$$

and for a given K_0.

λ and ν are the Lagrange multipliers associated to the resource and capital constraints. The optimal allocations satisfy the following nine conditions:

$$K_{t+1} = (1-\delta)\,K_t + \pi\,\left[F(K_{A,t},H_{A,t};\theta_{A,t}) - C_{A,t}\right] + (1-\pi)\,\left[F(K_{B,t},H_{B,t};\theta_{B,t}) - C_{B,t}\right] \quad (1)$$

$$K_t = \pi\,K_{A,t} + (1-\pi)\,K_{B,t} \quad (2)$$

$$\lambda_t = E_t\left[(1-\delta)\lambda_{t+1} + \nu_{t+1}\right], \quad (3)$$

for $J = A, B$:

$$U_1\left(C_{J,t}, 1-H_{J,t}\right) = \lambda_t \quad (4)$$

$$\frac{U_2\left(C_{J,t}, 1-H_{J,t}\right)}{F_2\left(K_{J,t}, H_{J,t};\theta_{J,t}\right)} = \lambda_t \quad (5)$$

$$F_1\left(K_{J,t}, H_{J,t};\theta_{J,t}\right) = \frac{\nu_t}{\lambda_t} \quad (6)$$

plus a transversality condition.

Finally, we define a news shock in country J as the announcement in period 0 that the technology index θ_J will change at date T. In other words, $E_0\left(\theta_{J,t}\right) = E_0\left(\theta_{J,0}\right)\ \forall\, 0 \leq t < T$ while $E_0\left(\theta_{J,t}\right) \neq E_0\left(\theta_{J,0}\right)\ \forall\, t \geq T$. T is referred to as the realization date, periods 0 to $T-1$ are denoted *iterim periods*.

Before we proceed to the analysis of the two-country equilibrium allocation, let us define its closed-economy analog, and put standard restrictions on it. The autarkic competitive equilibrium is the solution of the following social planner problem:

$$\max E_0 \sum_{t=0}^{+\infty} \beta^t\, U\left(C_t, 1-H_t\right)$$

subject to, for all $t \geq 0$

$$\begin{cases} K_{t+1} \leq (1-\delta)\,K_t + F(\mathcal{K}_t, H_t;\theta_t) - C_t & (\lambda_t) \\ K_t \geq \mathcal{K}_t & (\nu_t) \end{cases}$$

and K_0 given, where $\mathcal{K}_t$ denotes capital services used in the production process[1]. The constraints and first order conditions of the single country program write

$$K_{t+1} = (1-\delta)\,K_t + F(\mathcal{K}_t, H_t;\theta_t) - C_t \quad (7)$$

$$K_t = \mathcal{K}_t \quad (8)$$

$$\lambda_t = E_t\left[\lambda_{t+1}(1-\delta) + \nu_{t+1}\right] \quad (9)$$

[1] $\mathcal{K}_t$ can differ from the stock of physical capital available per capita K_t. The usefulness of introducing this variable will be come clear later.

$$\begin{aligned} U_1\left(C_t, 1-H_t\right) &= \lambda_t && (10) \\ \frac{U_2\left(C_t, 1-H_t\right)}{F_2\left(\mathcal{K}_t, H_t; \theta_t\right)} &= \lambda_t && (11) \\ F_1\left(\mathcal{K}_t, H_t; \theta_t\right) &= \frac{\nu_t}{\lambda_t} && (12) \end{aligned}$$

plus a transversality condition. Equations (7) to (12), which jointly define the autarkic allocation, are equivalent to (1) to (6) when $\pi = 1$ or $\pi = 0$. We make the following assumption.

Assumption (A): *Preference and technology are such that in the closed economy setup (7) to (12), an equilibrium allocation exists and is unique.*

1.1.2 Synchronization and Impossibility of Business Cycle Fluctuations

Turning back to the multi-country model, we show that news shocks are a powerful source of cross-country co-movements.

PROPOSITION 1 ***(Synchronization - One-Sector Economies)*** *Consider equilibrium allocations of the one-sector multi-country model with perfect and instantaneous mobility of capital after news shocks on θ_A or θ_B announced in period 0 for period T. Under assumption (A), those allocations are symmetric during the interim periods – i.e. from 0 to $T-1$.*

To prove this result, we need to characterize allocations during the interim period, from the announcement of the shock (period 0) to the period before its realization (period $T-1$). During those periods, all exogenous variable are constant, and we assume that they are symmetric across countries. Define a temporary equilibrium as the hyper plane defined by equations (1) to (2) and, for both country, (4) to (6). Those equations put restrictions on the endogenous variables *for given expectations* as defined in (3).

We propose here an intuition of the proof, leaving the formal proof of the existence and uniqueness of the symmetric solutions during the interim period for the appendix A. Consider period 0 (the period of the news). The shock materializes in the right hand side of equation (3), by a change in expectations. Equations (1) to (2) and, for both countries, (4) to (6) are not affected by the shock. The economy in period 0 has to move along those equations. Note now that for a given country J, equations (4) to (6) relate $(C_{J,0}, H_{J,0}, K_{J,0})$ to two multipliers (λ_0, ν_0) which are not country-specific and to exogenous variables $(\theta_{J,0})$ which are equal across country during the entire interim period. Therefore, equations (4) to (6) can be solved for $(C_{J,0}, H_{J,0}, K_{J,0})$ and the solution does not depends on J, meaning that the allocations are symmetric. This step requires that equations (4) to (6) can uniquely be solved for $(C_{J,t}, H_{J,t}, K_{J,t})$, which is what assumption (A) guarantees. Finally, equations (1) to (2) can be solved to obtain the two multipliers (λ_0, ν_0). The same line of argument can be repeated for all dates between 0 and $T-1$. In period T, technology changes in one of the two countries ($\theta_{A,T} \neq \theta_{B,T}$) and inputs get reallocated to the most productive economy, restoring the equality in marginal productivity of capital.

The synchronization result implies that consumption in both countries react in exactly the same way to changes in expectations, as do labor inputs, capital inputs, outputs and savings.[2] A shock expected to take place in only one of the two economies drives these economies perfectly symmetrically until the realization of the shock, at date T. Once the shock to θ gets realized, conditions (4) to (6) may drive these variables apart.

Note that this result does not depend on the nature of the shocks: fiscal or preference news shocks would also imply perfect symmetry. Remark as well that synchronization occurs in the interim period with country-specific news shocks as with common news shocks. If the underlying change in fundamental (here, θ_A or θ_B) is permanent, our result holds regardless of the joint asymptotic properties, such as the presence or absence of cointegration between θ_A or θ_B.

Synchronization is a cross-country feature. We are however also interested in within country co-movements: does the news shocks creates a domestic business cycle? The answer is no, as stated in the following proposition.

Proposition 2 ***(Domestic Business Cycles - One-Sector Economies)*** *Consider equilibrium allocations of the multi-country model with perfect and instantaneous mobility of capital after news shocks on θ_A or θ_B announced in period 0 for period T. During the interim periods, those allocations display negative correlation between consumption on the one side and investment and worked hours on the other side.*

The proof of this proposition relies on a previous result from Beaudry and Portier [2007] and on the following lemma.

Lemma 1 ***(Symetry/Autarky Equivalence)*** *When $\theta_{A,t} = \theta_{B,t}$, equilibrium allocations of any one of the two countries of the multi-country model coincide with an equilibrium allocation of the closed-economy model.*

[2]National investments cannot be defined in this setup where only the world stock of capital matters. When capital location is predetermined, variables listed in the main text remain synchronized from 0 to $T-1$ but national investment differ in $T-1$ to achieve different levels of capital per capita in period T. Time-to-build or capital adjustment costs at the country level would create a further tension regarding investment patterns. On one hand, the desire to equalize across countries the returns to capital pushes allocations of capital towards symmetry up to the last period. On the other hand, adjustment to (and away from) that target has to take place gradually.

The proof of this lemma is straightforward. When an equilibrium allocation of the two-country model is symmetric, *i.e.* $K_{A,t} = K_{B,t}$, $H_{A,t} = H_{B,t}$ and $C_{A,t} = C_{B,t}$, equations (1) to (6) imply (7) to (12). Reciprocally, the duplication of an autarkic equilibrium allocation is an allocation of the two-country model.

With Lemma 1, we can prove Proposition 2. Equilibrium allocations of the multi-country model are, during the interim period, allocations of a closed economy model. We know from Beaudry and Portier [2007] that one-sector closed-economy models cannot exhibit business cycle co-movements after changes in expectations. Hence, our one-sector two-country economy driven by news shock can exhibit cross-country positive co-movements, but cannot replicate within-country positive co-movements.[3]

We now extend our setup to a two-sector economy and show that the synchronization result remains valid.

1.2 Two-Sector Two-Country Model

1.2.1 The Setup

The production of the consumption good in country J requires capital, $K^c_{J,t}$, and labor, $H^c_{J,t}$. The production function $F^c\left(K^c_{J,t}, H^c_{J,t}; \theta^c_{J,t}\right)$ exhibits constant returns to scale and $\theta^c_{J,t}$ denotes the country-specific technology index in the consumption sector. Similarly, an homogenous investment good is produced using capital and labor with a constant returns to scale production function common to both countries, $F^x\left(K^x_{J,t}, H^x_{J,t}; \theta^x_{J,t}\right)$ for $J = A, B$ with $\theta^x_{J,t}$ the technology index in the investment sector.

Mobility of capital is perfect and instantaneous, both across countries and across sectors. Feasible allocations of capital satisfy $K_t \geq \pi\left(K^c_{A,t} + K^x_{A,t}\right) + (1-\pi)\left(K^c_{B,t} + K^x_{B,t}\right)$.

Consumption per capita is bounded above by the total production of the consumption good, while world investment is bounded above by the total production of the investment good. Denoting X_J the investment in country J, the law of motion of aggregate capital is

$$K_{t+1} \leq (1-\delta) K_t + \pi X_{A,t} + (1-\pi) X_{B,t}.$$

The social planner chooses $C_{J,t}$, $X_{J,t}$, $H^c_{J,t}$, $H^x_{J,t}$, $K^c_{J,t}$, $K^x_{J,t+1}$, for $J = A, B$, and K_{t+1} in order to

$$\max E_0 \sum_{t=0}^{+\infty} \beta^t \left[\pi U\left(C_{A,t}, 1 - H_{A,t}\right) + (1-\pi) U\left(C_{B,t}, 1 - H_{B,t}\right)\right]$$

[3] Consumption and labor input cannot comove after a news shock because the wealth effect drives consumption and leisure in the same direction. If consumption and investment comoved, output would follow them. This is impossible absent any current change in productivity.

subject to, for all $t \geq 0$

$$\begin{cases} \pi\, C_{A,t} + (1-\pi)\, C_{B,t} & \leq & \pi\, F^c\left(K^c_{A,t}, H^c_{A,t}; \theta^c_{A,t}\right) + (1-\pi)\, F^c\left(K^c_{B,t}, H^c_{B,t}; \theta^c_{B,t}\right) \\ \pi\, X_{A,t} + (1-\pi)\, X_{B,t} & \leq & \pi\, F^x\left(K^x_{A,t}, H^x_{A,t}; \theta^x_{A,t}\right) + (1-\pi)\, F^x\left(K^x_{B,t}, H^x_{B,t}; \theta^x_{B,t}\right) \\ K_t & \geq & \pi\left(K^c_{A,t} + K^x_{A,t}\right) + (1-\pi)\left(K^c_{B,t} + K^x_{B,t}\right) \\ H_{A,t} & \geq & H^x_{A,t} + H^c_{A,t} \\ H_{B,t} & \geq & H^x_{B,t} + H^c_{B,t} \\ K_{t+1} & \leq & (1-\delta)\, K_t + \pi\, X_{A,t} + (1-\pi)\, X_{B,t} \end{cases}$$

and K_0 given.

Assumption (A') is the analog in this multisector setup of (A) in the one-sector case.

Assumption (A'): *Preference and technology are such that in a closed economy setup, an equilibrium allocation exists and is unique.*

1.2.2 Synchronization and Possibility of Business Cycle Fluctuations

In the setup outlined in the preceding paragraph, we have the following result:

PROPOSITION 3 ***(Synchronization - Two-Sector Economies)*** *Consider equilibrium allocations of the multi-country model with perfect and instantaneous mobility of capital after news shocks on* $\theta^c_A, \theta^x_A, \theta^c_B$ *or* θ^x_B*, announced in period* 0 *for period* T*. Under assumption (A'), those allocations are symmetric during the interim periods – i.e. from* 0 *to* $T-1$*.*

To prove this result, we first need to define a multisectoral production function G that will help characterizing equilibrium allocations. We define $C_{J,t} = G(K_{J,t}, H_{J,t}, X_{J,t}; \theta_{J,t})$ as the value function of the static problem:

$$\max C_{J,t}$$

subject to

$$\begin{cases} C_{J,t} & \leq & F^c\left(K^c_{J,t}, H^c_{J,t}; \theta^c_{J,t}\right) \\ X_{J,t} & \leq & F^x\left(K^x_{J,t}, H^x_{J,t}; \theta^x_{J,t}\right) \\ K_{J,t} & \geq & K^x_{J,t} + K^c_{J,t} \\ H_{J,t} & \geq & H^x_{J,t} + H^c_{J,t} \end{cases}$$

with the notation $\theta_{J,t} = (\theta^c_{J,t}, \theta^x_{J,t})$. The interpretation of function G is the maximum level of consumption per capita achievable when investing $X_{J,t}$, using inputs $K_{J,t}$ and $H_{J,t}$ (and allocating them optimally across sectors) given technology $\theta_{J,t}$. It is easy to show that when the two production functions F^c and F^x are both Cobb-Douglas with the same coefficient, *i.e.* when the model boils down to a one-sector model, function G is of the form $G(K_{J,t}, H_{J,t}, X_{J,t}; \theta_{J,t}) = F(K_{J,t}, H_{J,t}; \theta_{J,t}) - X_{J,t}$.

With this definition, the social planner problem becomes very similar to the problem of the one-sector model.[4] It writes

$$\max E_0 \sum_{t=0}^{+\infty} \beta^t \left[\pi\, U\left(C_{A,t}, 1-H_{A,t}\right) + (1-\pi)\, U\left(C_{B,t}, 1-H_{B,t}\right)\right]$$

subject to for all $t \geq 0$

$$\left\{\begin{array}{rcll} \pi\, C_{A,t} + (1-\pi)\, C_{B,t} & \leq & \pi\, G(K_{A,t}, H_{A,t}, X_{A,t}; \theta_{A,t}) + (1-\pi)\, G(K_{B,t}, H_{B,t}, X_{B,t}; \theta_{B,t}) & (\lambda_t \geq 0) \\ K_{t+1} & \leq & (1-\delta)\, K_t + \pi\, X_{A,t} + (1-\pi)\, X_{B,t} & (\mu_t \geq 0) \\ K_t & \geq & \pi\, K_{A,t} + (1-\pi)\, K_{B,t} & (\nu_t \geq 0) \end{array}\right.$$

and K_0 given, with λ, μ and ν the Lagrange multipliers. The optimal allocations satisfy the following twelve constraints

$$\pi\, C_{A,t} + (1-\pi)\, C_{B,t} = \pi\, G(K_{A,t}, H_{A,t}, X_{A,t}; \theta_{A,t}) + (1-\pi)\, G(K_{B,t}, H_{B,t}, X_{B,t}; \theta_{B,t}) \tag{13}$$

$$K_{t+1} \leq (1-\delta)\, K_t + \pi\, X_{A,t} + (1-\pi)\, X_{B,t} \tag{14}$$

$$K_t \geq \pi\, K_{A,t} + (1-\pi)\, K_{B,t} \tag{15}$$

$$\mu_t = E_t\left[(1-\delta)\mu_{t+1} + \nu_{t+1}\right] \tag{16}$$

and for $J = A, B$

$$U_1\left(C_{J,t}, 1-H_{J,t}\right) = \lambda_t \tag{17}$$

$$\frac{U_2\left(C_{J,t}, 1-H_{J,t}\right)}{G_2\left(K_{J,t}, H_{J,t}, X_{J,t}; \theta_{J,t}\right)} = \lambda_t \tag{18}$$

$$-G_3\left(K_{J,t}, H_{J,t}, X_{J,t}; \theta_{J,t}\right) = \frac{\mu_t}{\lambda_t} \tag{19}$$

$$G_1\left(K_{J,t}, H_{J,t}, X_{J,t}; \theta_{J,t}\right) = \frac{\nu_t}{\lambda_t} \tag{20}$$

plus a transversality condition.

As in the one-sector model, the temporary equilibrium is the hyper plane defined by equations (13) to (15) and, for both country, (17) to (20). Expectations are taken as given from (16). Equations (17) to (20) relate allocations$(C_{J,0}, H_{J,0}, X_{J,0}, K_{J,0})$ to three multipliers $(\lambda_0, \mu_0, \nu_0)$ which are not country specific and to exogenous variables $(\theta_{J,0})$ which are equal across country from 0 to $T-1$. Therefore, equations (17) to (20) can be solved for $(C_{J,0}, H_{J,0}, X_{J,0}, K_{J,0})$ and the solution does not depends on J, meaning that the allocations are symmetric.[5] In period T, the news shock is realized and conditions (17) to (20) no longer impose symmetry. Once again, the synchronization of allocations in A and B holds regardless of the nature of the news.

[4] For that reason, an extension to a n–sector model, $n > 2$, is straightforward.

[5] This argument relies on assumption (A') which ensures that equations (17) to (20) can always be solved for $(C_{J,t}, H_{J,t}, X_{J,t}, K_{J,t})$. This is not always the case. For example, in the one-sector particular case, $G_3 = -1$ and the system (17) to (20) is singular.

As the symmetry result obtained in the one-sector economy still holds in a two-sector setup, the impossibility of business cycles fluctuations also holds in two-sector models. As allocations are symmetrical, the two-sector-two-country economy boils down to twice a two-sector closed economy[6]. We can therefore use the result in Beaudry and Portier [2007] that shows the impossibility of having positive movements of consumption, investment and hours following an news shock in a two-sector closed economy. This impossibility hinges on the restrictions that the two-sector setup imposes on the function G. Beaudry and Portier [2007] also show that the impossibility of news driven business cycles is not general in multi-sectoral models with more than two sectors. The setup is one in which the function $G(K, H, X; \theta)$ is not derived from a two-sector model, but is simply assumed to be a constant-return function that is convex in X and concave in K and H. Allocations are still given by equations (13) to (15) and, for both country, (17) to (20). In such a multi-sector setup, domestic business cycles are now possible, as stated in Proposition 4.

PROPOSITION 4 ***(Domestic Business Cycles - Multi-Sector Economies)*** *Consider equilibrium allocations of the multi-sector multi-country model with perfect and instantaneous mobility of capital after news shocks on $\theta_A^c, \theta_A^x, \theta_B^c$ or θ_B^x, announced in period 0 for period T. During the interim periods, allocations with positive co-movements between domestic consumption, investment and hours are possible. A necessary condition for those co-movements is $G_{23} \geq 0$.*

The proof of this proposition is a simple extension of a result found in Beaudry and Portier [2007]. Again, as allocations are symmetrical, the multi-sector-two-country economy reduces to twice a multi-sector closed economy, and we can therefore replicate the analysis of Beaudry and Portier [2007]. Fully differentiation of the static condition for allocation of consumption and leisure, combined with (17) and (18) gives:

$$\frac{U_2\left(C_{J,t}, 1-H_{J,t}\right)}{G_2\left(K_{J,t}, H_{J,t}, X_{J,t}; \theta_{J,t}\right)} = U_1\left(C_{J,t}, 1-H_{J,t}\right) \Rightarrow dH_{J,t} = a_1^J\left(-a_2^J\, dC_{J,t} + a_3^J\, dX_{J,t}\right)$$

$$\text{with } \left\{\begin{array}{lcl} a_1^J & = & -\left[-U_{12}\left(C_{J,t}, 1-H_{J,t}\right) G_2\left(K_{J,t}, H_{J,t}, X_{J,t}; \theta_{J,t}\right) + U_1\left(C_{J,t}, 1-H_{J,t}\right) G_{22}\left(K_{J,t}, H_{J,t}, X_{J,t}; \theta_{J,t}\right)\right. \\ & & \left. +U_{22}\left(C_{J,t}, 1-H_{J,t}\right)\right]^{-1} > 0 \\ a_2^J & = & -U_{11}\left(C_{J,t}, 1-H_{J,t}\right) G_2\left(K_{J,t}, H_{J,t}, X_{J,t}; \theta_{J,t}\right) - U_{21}\left(C_{J,t}, 1-H_{J,t}\right) < 0 \\ a_3^J & = & U_1\left(C_{J,t}, 1-H_{J,t}\right) G_{23}\left(K_{J,t}, H_{J,t}, X_{J,t}; \theta_{J,t}\right) \gtreqless 0. \end{array}\right.$$

Full differentiation of the resource constraint gives

$$dC_{J,t} = G_2\left(K_{J,t}, H_{J,t}, X_{J,t}; \theta_{J,t}\right) dH_{J,t} + G_3\left(K_{J,t}, H_{J,t}, X_{J,t}; \theta_{J,t}\right) dX_{J,t}.$$

[6]Note that this is true only during the interim period.

Combining those two last equations, we obtain

$$\left[1 - G_2\left(K_{J,t}, H_{J,t}, X_{J,t}; \theta_{J,t}\right)\, a_1^J\, a_2^J\right] dC_{J,t} = \left[G_2\left(K_{J,t}, H_{J,t}, X_{J,t}; \theta_{J,t}\right)\, a_1^J\, a_3^J + G_3\left(K_{J,t}, H_{J,t}, X_{J,t}; \theta_{J,t}\right)\right]\, dX_{J,t}.$$

If $G_{23} < 0$, then $a_3^J < 0$ and consumption and investment exhibit a negative correlation, so that $G_{23} \geq 0$ is a necessary condition for positive co-movements of consumption, investment and hours within a country.

We have shown in this section that local news shocks are synchronizing economies, but that they fail to create domestic business cycle fluctuations in standard one and two-sector setups. In the next section, we propose three-sector model (that can be reinterpreted as a particular two-sector model with $G_{23} = 0$) in which local news shocks do create a domestic business cycle that is transmitted abroad. We contrast the quantitative responses that we obtain with those of more standard BKK-type models.

2 The International Transmission of News Shock in a Two-Country-Two-Sector Model

As established in the previous section, a domestic productivity news shock may act as a synchronizing force in international business cycles, but not in standard international business cycle models for at least two reasons

First, news shocks will move consumption on the one hand and investment and hours on the other hand in opposite directions during the interim period (from 0 to T). Following a good news about future technology in country A , the representative agent of both economies is wealthier, as one of the asset in her portfolio (capital located in A) will serve higher return in the future. The two representative agents therefore consume more of all normal goods, typically consumption and leisure. As technology has not yet improved, productivity of labor is not higher, and therefore no substitution effect pushes labor supply upwards. As a result, worked hours fall and consumption rises in both countries. The only way to finance this consumption boom is therefore a drop in investment in both countries.

Second, when the local technological improvement occurs (in period T), it is well-known that models have trouble in reproducing the cross-country correlation of inputs (the so-called "input anomaly"). There are strong incentives to use productive inputs more intensively in the country benefiting from a positive productivity differential. This leads to negative cross-correlations of output, investment and labor input.

In this section, we first propose a two-country version of a model introduced by Beaudry and

Portier [2004]. We show that the model is able to generate international co-movements and domestic business cycle following a news shock. We then show that quantitative versions of one or two sectors BKK-like models fail generating such a response of the economy to a news shock.

2.1 A Two-Country Multi-sector Model

There are four building blocks in the model. First, there are two sectors for final use goods in each country, one producing the local consumption good and one producing the local investment good. The multi-good structure has been shown to be needed for news-driven business cycles, but also to help solving the input anomaly. Second, there are static gains to trade in the model. There are in each country two sectors of intermediate goods, one consumption–oriented (meaning that this intermediate good will enter in the production of consumption) and one investment–oriented (meaning that this intermediate good will enter in the production of investment). Consumption and investment are then produced in each country with a CES aggregator of home and foreign intermediate goods. This assumption is helpful to deal with the input anomaly. Third, capital and labor are complementary in the consumption–oriented intermediate good sector. This implies that investment is needed to take advantage of a good news in the interim period and increasing consumption. Capital–labor complementarity creates an incentive to increase both investment and consumption. Fourth, we assume that reallocation of inputs between the consumption and investment good sector is costly, so that increasing consumption in the interim period cannot be done easily by shifting resources away from the investment good sector. Formally, we assume that labor is the only variable factor in the production of the investment-oriented intermediate good. This last assumption, by preventing capital reallocation in the business cycle, helps creating the positive response of all macroeconomic aggregates to news shocks. A less extreme assumption would be to introduce adjustment cost of capital reallocation but this would further increase the model dimension.

Those four building blocks allow us to generate news-driven international co-movements. We now expose in more details the structure of the economy. We consider a stylized economy composed of two countries, A and B, which are symmetric, with respective population N_A and N_B.

Final goods. There are two final-use sectors: a consumption goods sector and an investment one. The consumption good sector of country A combines two intermediate goods, Z_{AA} which is produced home and Z_{BA} which is imported from country B[7], to produce the consumption good, according to

[7] We adopt here the following notation: Z_{IJ} means good Z produced in I and used in J.

the following constant returns CES aggregator:

$$C_{A,t} = \left[b_C Z_{AA,t}^{\nu_C} + (1 - b_C)\, Z_{BA,t}^{\nu_C}\right]^{\frac{1}{\nu_C}},\ 0 < b_C < 1. \tag{21}$$

The analogue consumption bundle for country B writes

$$C_{B,t} = \left[(1 - b_C)\, Z_{AB,t}^{\nu_C} + b_C Z_{BB,t}^{\nu_C}\right]^{\frac{1}{\nu_C}}. \tag{22}$$

Similarly, the final investment good in country A is produced by combining two intermediate goods, X_{AA} which is produced home and X_{BA} which is imported from country B, according to

$$I_{A,t} = \left[b_I X_{AA,t}^{\nu_I} + (1 - b_I)\, X_{BA,t}^{\nu_I}\right]^{\frac{1}{\nu_I}},\ 0 < b_I < 1.$$

Investment in each country is then used to increment the domestic stock of capital:

$$K_{A,t+1} = (1 - \delta)\, K_{A,t} + I_{A,t} = (1 - \delta)\, K_{A,t} + \left[b_I X_{AA,t}^{\nu_I} + (1 - b_I)\, X_{BA,t}^{\nu_I}\right]^{\frac{1}{\nu_I}} \tag{23}$$

and

$$K_{B,t+1} = (1 - \delta)\, K_{B,t} + I_{B,t} = (1 - \delta)\, K_{B,t} + \left[(1 - b_I)\, X_{BA,t}^{\nu_I} + b_I X_{BB,t}^{\nu_I}\right]^{\frac{1}{\nu_I}}. \tag{24}$$

Intermediate goods. Country A produces a consumption-oriented intermediate good Z_A using capital and labor H_A according to the following CES technology:

$$Z_{A,t} = \left[a\left(\theta_{A,t}\overline{H}_{A,Z}^{1-\varphi} H_{A,t}^{\varphi}\right)^{\nu} + (1 - a) K_{A,t}^{\nu}\right]^{\frac{1}{\nu}}. \tag{25}$$

$\theta_{A,t}$ denotes the technology index which will serve as the exogenous driving force, $\overline{H}_{A,Z}$ represents some fixed labor required in the production of the consumption-oriented intermediate good. We will restrict attention to cases where the elasticity of substitution between K and labor in the final goods sector is no greater that one. This intermediate good is then either used at home (Z_{AA}) or exported (Z_{AB}).

Country A also produces a investment-oriented intermediate good X_A using variable labor $\widetilde{H}_A$ according to the following technology:

$$X_{A,t} = \widetilde{\theta}_{A,t}\overline{K}_A^{1-\alpha_X-\beta_X}\overline{H}_{A,X}^{\beta_X}\widetilde{H}_{A,t}^{\alpha_X}. \tag{26}$$

$\widetilde{\theta}_{A,t}$ denotes the technology index in the investment-oriented intermediate good sector. We assume that some labor $\overline{H}_{A,X}$ and all the capital used in this sector $\overline{K}_A$ are in fixed quantity. As we explained, the absence of possibility of reallocating capital between the two-sectors is crucial to obtain news-driven business cycles.

In country B, the analogue consumption-oriented and investment-oriented intermediate goods write respectively

$$Z_{B,t} = \left[a \left(\theta_{B,t} \overline{H}_{B,Z}^{1-\varphi} H_{B,t}^{\varphi} \right)^{\nu} + K_{B,t}^{\nu} \right]^{\frac{1}{\nu}} \tag{27}$$

and

$$X_{B,t} = \widetilde{\theta}_{B,t} \overline{K}_{B}^{1-\alpha_X-\beta_X} \overline{H}_{B,X}^{\beta_X} \widetilde{H}_{B,t}^{\alpha_X}. \tag{28}$$

Preferences. The representative household of country A has preferences over individual consumption and hours worked at all periods, discounts period utility at rate β and we assume that the period utility is of the Hansen-Rogerson type:

$$\mathcal{U}_A \left(c_{A,t}, h_{A,t}, \widetilde{h}_{A,t} \right) = \ln c_{A,t} - \chi \left(h_{A,t} + \widetilde{h}_{A,t} + \overline{h}_A \right)$$

The country B agent preferences are similar to country A ones.

2.2 Equilibrium Allocations

The two welfare theorems apply in this setup and we solve for an optimal allocation. The Social Planner chooses $\left\{ c_{J,t},\, h_{J,t},\, \widetilde{h}_{J,t},\, I_{J,t},\, K_{J,t+1},\, Z_{IJ} \right\}_{J=A,B}$ in order to

$$\max E_0 \sum_{t=0}^{+\infty} \beta^t \left[N_A \left(\ln c_{A,t} - \chi \left(h_{A,t} + \widetilde{h}_{A,t} + \overline{h}_A \right) \right) + N_B \left(\ln c_{B,t} - \chi \left(h_{B,t} + \widetilde{h}_{B,t} + \overline{h}_B \right) \right) \right]$$

subject to conditions (21) to (28) and the following resource conditions

$$\left\{ \begin{array}{rcl} C_{A,t} & = & N_A c_{A,t} \\ C_{B,t} & = & N_B c_{B,t} \\ H_{A,t} & = & N_A h_{A,t} \\ H_{B,t} & = & N_B h_{B,t} \\ \widetilde{H}_{A,t} & = & N_A \widetilde{h}_{A,t} \\ \widetilde{H}_{B,t} & = & N_B \widetilde{h}_{B,t} \\ Z_{A,t} & \geq & Z_{AA,t} + Z_{AB,t} \\ Z_{B,t} & \geq & Z_{BA,t} + Z_{BB,t} \\ X_{A,t} & \geq & X_{AA,t} + X_{AB,t} \\ X_{B,t} & \geq & X_{BA,t} + X_{BB,t} \\ N_A \overline{h}_A & \geq & \overline{H}_{A,X} + \overline{H}_{A,Z} \\ N_B \overline{h}_B & \geq & \overline{H}_{B,X} + \overline{H}_{B,Z} \\ K_{A,0} & = & K_{B,0} \;\; \text{given,} \end{array} \right.$$

where small letters denote per capita variables.

Once this social optimum problem solved, one can backup prices and National Income and Product Accounts. We assume that the consumption good in country A is the numéraire. For $I \in \{A, B\}$,

q_I will denote the price of the investment good, p_I the price of the consumption good (with $p_A = 1$) and w_I the wage rate. We define nominal GDP of country I as $p_I C_I + q_I I_I$. Period 0, in which the economy is at the steady-state, is chosen as the base period. Using a subscript S for steady state values, real GDP in any period will be computed as $p_I^S C_I + q_I^S I_I$. Baskets of imports and of exports are computed in the same way, using period 0 as the base period for prices. Finally, Total Factor Productivity will be measured as if the model was a one-sector Cobb-Douglas economy

$$TFP_{I,t} = \frac{p_I^S C_I + q_I^S I_I}{K_{I,t}^{1-sh}(H_{I,t} + \widetilde{H}_{I,t})^{sh}}$$

where sh is the steady state labor income share.

Because the model has no analytical solution, we turn to numerical analysis.

2.3 Numerical Response to a News

We propose here a numerical analysis of the model allocations following a news shock on productivity in one country. The period is one quarter. We assume that the two countries have the same size, normalize productivity θ_I to 1 and set β to .984. Parameters $\widetilde{\theta}$, a, χ, b and δ are set to match the following steady-state values: consumption to GDP ratio is .7, labor income is 2/3 of GDP, imports and exports represent 25% of GDP each and capital to annual GDP ratio is 1.25.

For the elasticity of substitution between domestic and foreign intermediate goods, we choose a value of 0.4, meaning that the two intermediate goods are complementary. This level of elasticity is at the bottom end what is generally chosen in the literature. As we do not allow for any common component in shocks, relatively strong complementarities are needed for local technological shocks to generate positive co-movements when implemented. On the contrary, complementarity is not needed for the response to news as during the interim period: the two countries comove positively regardless of the degree of complementarity. Finally, capital and labor are assumed to be complementary in the production of the consumption-oriented intermediate goods, with elasticity 0.2. This elasticity is the one estimated by Beaudry and Portier [2004]. α_X, β_X and ϕ are also taken from Beaudry and Portier [2004].

A technological news in the investment-oriented sector will create a wealth effect and an incentive to postpone investment, and is therefore unlikely to generate a joint increase of consumption and investment. Therefore, we study the response of the economy to a non–expected permanent technological shock in the consumption-oriented intermediate good sector of country A, $\theta_{A,t}$. Other technological parameters are maintained constant. As identified in Beaudry and Portier [2006], we

Table 1: Two-Country Multi-Sector and BKK Models Parameters Values

		Pigou Model	One-sector BKK Model	Two-sector BKK Model
N_a, N_b	:	1	1	1
a	:	.01	-	.01
b_C	:	.94	-	.94
b_I	:	.94	-	.94
b	:	-	.83	-
ϕ	:	.6	-	-
ν	:	-3.78	-	-
ν_C, ν_I	:	-1.5	-	-1.5
ν	:	-.5	-	-
α_X	:	.97	-	.1
β_X	:	0	-	
α_Z	:	-	-	.41
α	:	-	1/3	-
χ	:	.1225	1	1
δ	:	.06	.06	.05
β	:	.984	.984	.984
θ	:	1	1	1
$\widetilde{\theta}$	:	.15	-	.15
ρ	:	.8	.8	.8
N	:	4	4	4

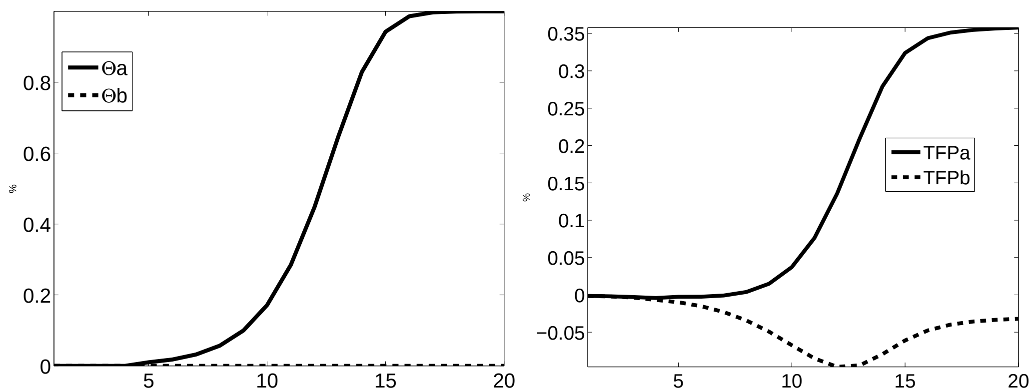
assume that technological improvements slowly diffuse. More specifically, $\theta_{A,t}$ follows:

$$\theta_{A,t} = 1 + \frac{u_{A,t}}{100} \quad (29)$$

$$u_{A,t} = u_{A,t-1} + \rho\left(u_{A,t-1} \times (1 - u_{A,t-1})\right) + \varepsilon_{A,t-t} \quad (30)$$

with $\rho = .8$. The economy is supposed to be at steady state before period 0, with $u_{A,0} = 0$ and $\theta_{A,0} = 0$. The economy is hit in period 0 by a shock $\varepsilon_{A,0} = 1\%$. The shock does not affect productivity for the first T periods, although it is observed in period 0 by the agent. After implementation, u_t slowly increases and asymptotically reaches 1, so that $\theta_{A,t}$ permanently increases by 1%. We assume $T = 4$. The evolution of θ as well as the response of measured TFP are displayed on Figure 1. Notice that before period 10, θ_A is not larger than .1 %. Also notice that measured aggregate TFP[8] is contaminated, and weakly decreasing in country B. This comes from the fact that, due to fixed factors, returns are slightly decreasing in the economy.

Figure 1: Pigou Model, Technological News in Country A



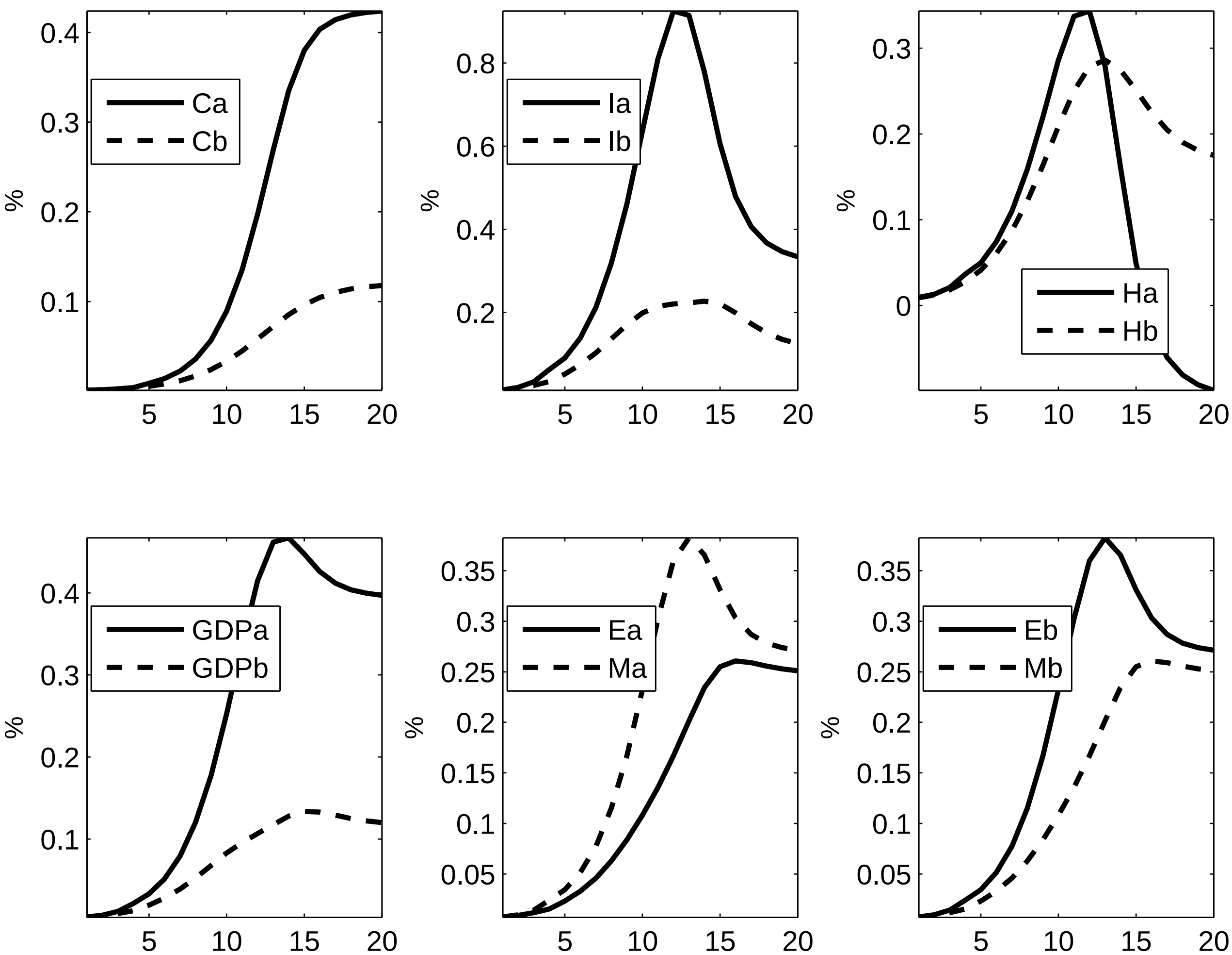
In this Figure, we display the time path of technology in the consumption-oriented intermediate good sector θ (left panel) as well as the response of measure TFP in the two countries. In period 1, agents learn that technology of country A will start diffusing in period 5 and eventually increase by one percent. All variables are expressed in percentage deviation from their steady-state level. The parameters values are the ones of Table 1.

Figure 2 displays the response of the economy to this shock. Let us first consider the first ten periods. Absent of any changes on current fundamentals (the first four periods), or with virtually no technological change (periods 5 to 10), the two economies experience an aggregate boom: GDP, consumption, investment and hours increase in both countries, more so in country A that in country B. Note that imports increase more than exports in country A, while the opposite happens in country

[8] Measured aggregate TFP is what would compute an economist assuming that the data are generated by a one-sector Cobb-Douglas production function.

B: the news shocks act as a demand shock in country A, that runs a trade balance deficit. When the technological improvement is partially implemented (say 15 period after the news), work hours start decreasing in country A, but stay above their steady state level, while investment is also decreasing in country B (but again stays above steady state), as capital gets reallocated to country A. At this point, country A net exports become larger but stay negative. We only focus here on the conditional response to news shocks. The computation of cyclical unconditional moments in models including various shocks is left for future research.

Figure 2: Pigou Model, Technological News in Country A



In this Figure, we display the response to a technological news that is specific to country A. In period 1, agents learn that technology will start diffusing in period 5 and eventually increase by one percent in country A. All variables are expressed in percentage deviation from their steady-state level. The parameters values are the ones of Table 1.

2.4 International Transmission of News Shocks in More Standard Settings

Is the (relatively) non-standard setup of the multi-sector model necessary? Although we do not claim that this is the unique way of obtaining news-driven international business cycles[9], we have outlined above that regular models cannot generate international business cycles. Here we illustrate quantitatively this claim with two versions of the most well accepted flex-price and complete market model, that is inspired from the seminal work of Backus, Kehoe, and Kydland [1994]. The first version is a one-sector model, while the second is a two-sector one.

2.4.1 A one-sector BKK model.

We briefly expose the building blocks of the model.

Final goods. There is one final good per country, that is used for both consumption and investment purposes. This good is obtained by combining intermediate goods produced home and abroad. Therefore, countries final good resource constraints are given by:

$$\begin{aligned} C_{A,t} + I_{A,t} &= \left[b Z_{AA,t}^{\nu} + (1 - b_C)\, Z_{BA,t}^{\nu} \right]^{\frac{1}{\nu}} \\ C_{B,t} + I_{B,t} &= \left[(1-b) Z_{AB,t}^{\nu} + b Z_{BB,t}^{\nu} \right]^{\frac{1}{\nu}} \end{aligned}$$

Investment in each country is then used to increment the domestic stock of capital:

$$K_{A,t+1} = (1 - \delta)\, K_{A,t} + I_{A,t}$$

$$K_{B,t+1} = (1 - \delta)\, K_{B,t} + I_{B,t}$$

Intermediate goods. Each country A and B produces a country-specific intermediate good that is used domestically and exported:

$$\begin{aligned} Z_{AA,t} + Z_{AB,t} &= \Theta_{A,t} K_{A,t}^{\alpha} H_{A,t}^{1-\alpha_X} \\ Z_{BA,t} + Z_{BB,t} &= \Theta_{B,t} K_{B,t}^{\alpha} H_{B,t}^{1-\alpha_X} \end{aligned}$$

Preferences. The representative household of each country has preferences over individual consumption and hours worked at all periods. We keep the Hansen-Rogerson functional form:

$$\begin{aligned} U_A &= \sum_{t=0}^{\infty} \beta^t \; \left[\ln c_{A,t} - \chi h_{A,t} \right] \\ U_B &= \sum_{t=0}^{\infty} \beta^t \left[\ln c_{B,t} - \chi h_{B,t} \right] \end{aligned}$$

[9] See for example the model of Jaimovich and Rebelo [2006] and the small open-economy extension they propose in Jaimovich and Rebelo [2007].

2.4.2 A two-sector BKK model.

This version is close to the Pigou model, except that both production functions of intermediate goods are Cobb-Douglas.

Final goods. There are two final-use sectors: a consumption goods sector and an investment one. The consumption good sector of country A combines two intermediate goods, Z_{AA} which is produced home and Z_{BA} which is imported from country B, to produce the consumption good, according to the following constant returns CES aggregator:

$$C_{A,t} = \left[b_C Z_{AA,t}^{\nu_C} + (1 - b_C) Z_{BA,t}^{\nu_C}\right]^{\frac{1}{\nu_C}},\ 0 < b_C < 1. \tag{31}$$

The analogue consumption bundle for country B writes

$$C_{B,t} = \left[(1 - b_C) Z_{AB,t}^{\nu_C} + b_C Z_{BB,t}^{\nu_C}\right]^{\frac{1}{\nu_C}}. \tag{32}$$

Similarly, the final investment good in country A is produced by combining two intermediate goods, X_{AA} which is produced home and X_{BA} which is imported from country B, according to

$$I_{A,t} = \left[b_I X_{AA,t}^{\nu_I} + (1 - b_I) X_{BA,t}^{\nu_I}\right]^{\frac{1}{\nu_I}},\ 0 < b_I < 1.$$

Investment in each country is then used to increment the domestic stock of capital:

$$K_{A,t+1} = (1 - \delta) K_{A,t} + I_{A,t} = (1 - \delta) K_{A,t} + \left[b_I X_{AA,t}^{\nu_I} + (1 - b_I) X_{BA,t}^{\nu_I}\right]^{\frac{1}{\nu_I}} \tag{33}$$

and

$$K_{B,t+1} = (1 - \delta) K_{B,t} + I_{B,t} = (1 - \delta) K_{B,t} + \left[(1 - b_I) X_{BA,t}^{\nu_I} + b_I X_{BB,t}^{\nu_I}\right]^{\frac{1}{\nu_I}}. \tag{34}$$

Intermediate goods. Country A produces a consumption-oriented intermediate good Z_A using capital K_A^Z and labor H_A^Z according to the following Cobb-Douglas technology:

$$Z_{A,t} = \theta_{A,t}(K_{A,t}^Z)^{\alpha_z}(H_{A,t}^Z)^{1-\alpha_z} \tag{35}$$

Country A also produces a investment-oriented intermediate good X_A using capital K_A^X and labor H_A^X according to the following Cobb-Douglas technology:

$$X_{A,t} = \widetilde{\theta}_{A,t}(K_{A,t}^X)^{\alpha_x}(H_{A,t}^X)^{1-\alpha_x} \tag{36}$$

In country B, the analogue consumption-oriented and investment-oriented intermediate goods write respectively

$$Z_{B,t} = \theta_{B,t}(K_{B,t}^Z)^{\alpha_z}(H_{A,t}^B)^{1-\alpha_z} \tag{37}$$

and

$$X_{B,t} = \widetilde{\theta}_{B,t}(K^X_{B,t})^{\alpha_x}(H^X_{B,t})^{1-\alpha_x} \tag{38}$$

The total capital stock in each country is predetermined and is split between the two intermediate good sectors:

$$K_{A,t} = K^X_{A,t} + K^Z_{A,t} \tag{39}$$

$$K_{B,t} = K^X_{B,t} + K^Z_{B,t} \tag{40}$$

Preferences. The representative household of country A has preferences over individual consumption and hours worked at all periods, discounts period utility at rate β and we assume that the period utility is of the Hansen-Rogerson type:

$$\mathcal{U}_A\left(c_{A,t}, h_{A,t}, \widetilde{h}_{A,t}\right) = \ln c_{A,t} - \chi\left(h_{A,t} + \widetilde{h}_{A,t} + \overline{h}_A\right)$$

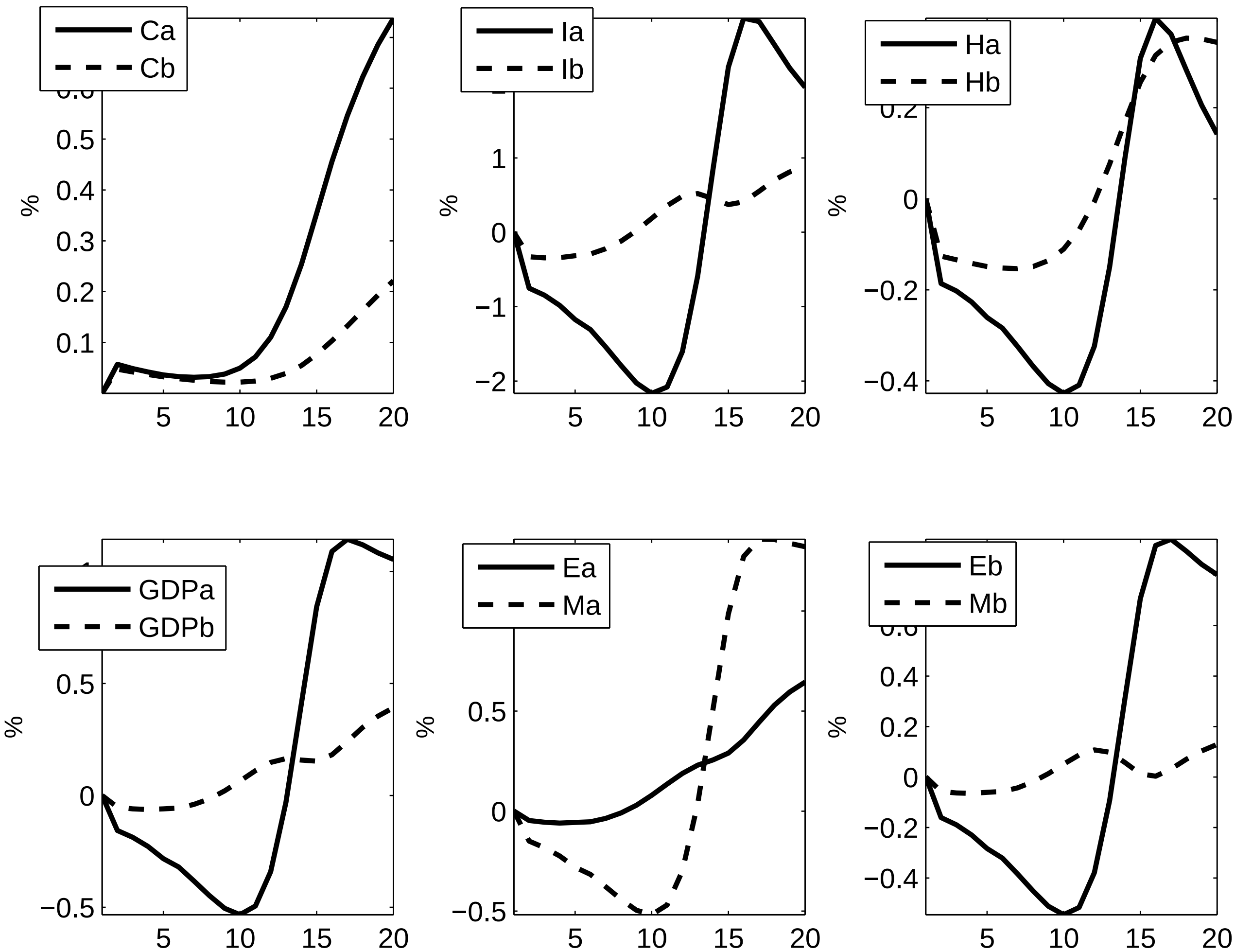
The country B agent preferences are similar to country A ones.

2.4.3 Numerical Responses to a News Shock.

The two models model are calibrated to match the same steady state properties than previously: consumption to GDP ratio is .7, labor income is 2/3 of GDP, imports and exports represent 25% of GDP each and capital to annual GDP ratio is 1.25. As previously, we assume strong complementarity between home and foreing goods (elasticity of substitution equal to 0.2).

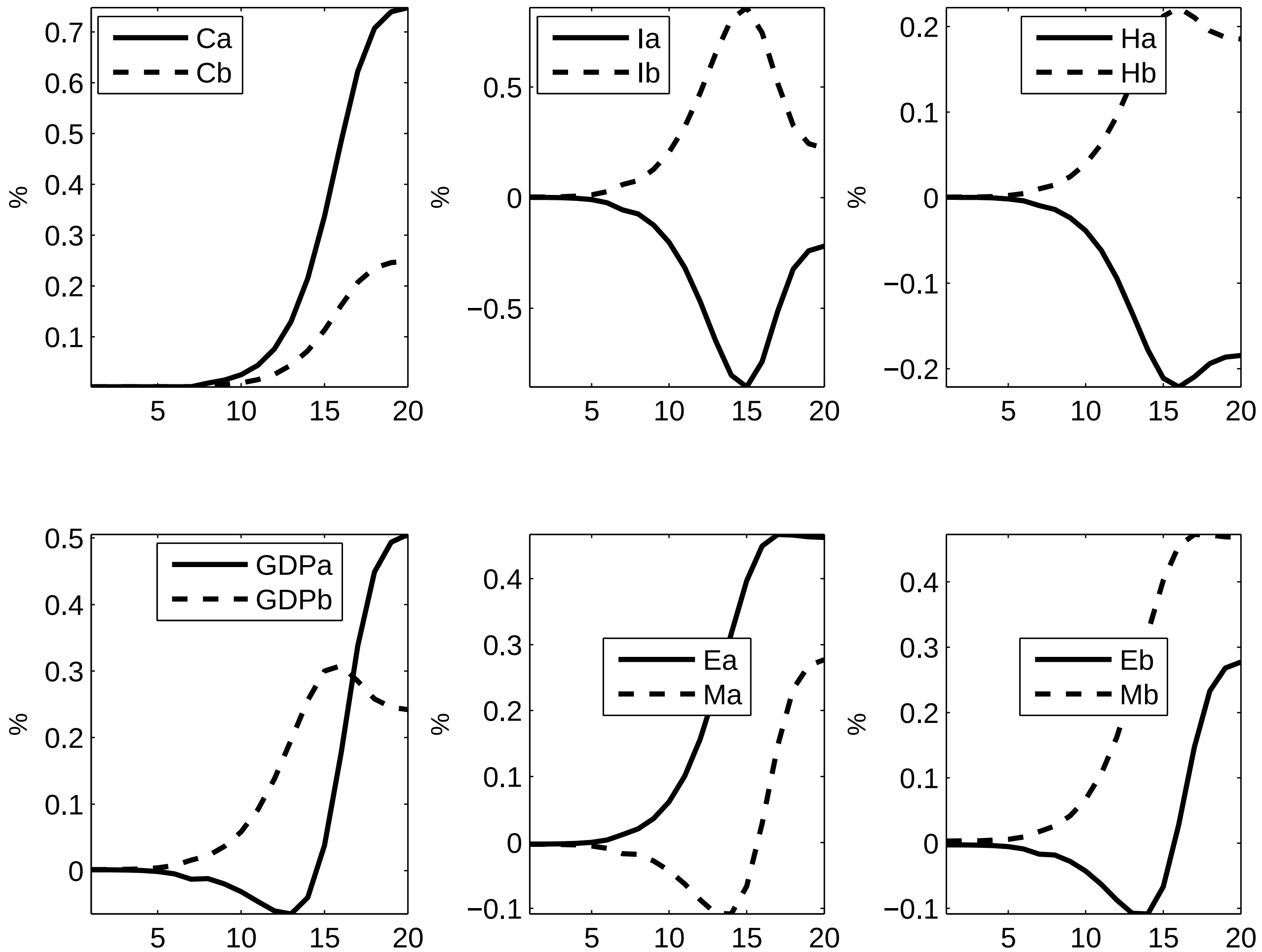
The responses of the economy to a local (country A) technology shock similar to the one shown on Figure 1 are displayed on Figures 3 and 4. Both models dramatically fails in producing a home expansion: consumption increases in both countries, but investment and employment fall during the first ten periods, before effective implementation of the technological improvement. Investment and hours recession is exported abroad during the first ten periods, and international trade collapses. When the technology actually improves (after period ten), one observes a boom in both countries, country A's boom being exported because home and foreign goods are complementary in the production function. The model therefore fails in generating international business cycles.

Figure 3: One-Sector BKK Model, Technological News in Country A



In this Figure, we display the response to a technological news that is specific to country A. In period 1, agents learn that technology will start diffusing in period 5 and eventually increase by one percent in country A. All variables are expressed in percentage deviation from their steady-state level. The parameters values are the ones of Table 1.

Figure 4: Two-Sector BKK Model, Technological News in Country A



In this Figure, we display the response to a technological news that is specific to country A. In period 1, agents learn that technology will start diffusing in period 5 and eventually increase by one percent in country A. All variables are expressed in percentage deviation from their steady-state level. The parameters values are the ones of Table 1.

Conclusion

In this paper, we have addressed the question of business cycle co-movements within and between countries. First, we have shown that news shocks are potentially a powerful source of joint co-movements across countries We then have proposed a two-country-two-sector model that allows for news shocks to propagate and generate international business cycles. We have also shown that canonical two-country RBC model were not able to generate news-driven national and international business cycles. Two extensions of this analysis are work in progress. First, we show in Beaudry, Dupaigne, and Portier [2009] that technological news are indeed found in the data, as well in the U.S. and in Germany. We also show that those news do propagate to Canada (for the U.S.) and Austria (for Germany), generating international business cycles. Second, we need to investigate whether a model along the lines presented here also replicates unconditional moments of international business cycles when some other shocks are introduced in the analysis.

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Appendix

A Proof of the Synchronisation Result

We first prove the existence of a solution which is symmetric during the interim period. Under assumption (A), the closed economy problem has a unique solution for any initial condition K_0: a vector $\left(\mathcal{K}_t^{ce}, H_t^{ce}, C_t^{ce}, K_{t+1}^{ce}, \lambda_t^{ce}, \nu_t^{ce}\right)$ which satisfies

$$K_{t+1}^{ce} = (1-\delta)\,K_t^{ce} + F(\mathcal{K}_t^{ce}, H_t^{ce};\theta_t) - C_t^{ce} \tag{41}$$

$$K_t^{ce} = \mathcal{K}_t^{ce} \tag{42}$$

$$\lambda_t^{ce} = E_t\left[\lambda_{t+1}^{ce}(1-\delta) + \nu_{t+1}^{ce}\right] \tag{43}$$

$$U_1\left(C_t^{ce}, 1-H_t^{ce}\right) = \lambda_t^{ce} \tag{44}$$

$$\frac{U_2\left(C_t^{ce}, 1-H_t^{ce}\right)}{F_2\left(\mathcal{K}_t^{ce}, H_t^{ce};\theta_t\right)} = \lambda_t^{ce} \tag{45}$$

$$F_1\left(\mathcal{K}_t^{ce}, H_t^{ce};\theta_t\right) = \frac{\nu_t^{ce}}{\lambda_t^{ce}} \tag{46}$$

Conditions (43) to (46) are equivalent to conditions (3) to (6),

$$(41) \Rightarrow K_{t+1}^{ce} = (1-\delta)\,K_t^{ce} + \pi\,\left[F\left(\mathcal{K}_t^{ce}, H_t^{ce};\theta_t\right) - C_t^{ce}\right] + (1-\pi)\,\left[F\left(\mathcal{K}_t^{ce}, H_t^{ce};\theta_t\right) - C_t^{ce}\right]$$

and

$$(42) \Rightarrow K_t^{ce} = \pi\,\mathcal{K}_t^{ce} + (1-\pi)\,\mathcal{K}_t^{ce}.$$

Hence, between periods 0 and $T-1$, the allocation $(K_{J,t}, H_{J,t}, C_{J,t}) = (\mathcal{K}_t^{ce}, H_t^{ce}, C_t^{ce})$ for $J = A, B$, $K_{t+1} = K_{t+1}^{ce}$ and $(\lambda_t, \nu_t) = (\lambda_t^{ce}, \nu_t^{ce})$ satisfies the nine conditions (1) to (6). This proves the existence of a solution of the two-country problem with initial capital per capita K_0. By construction, this equilibrium allocation is perfectly symmetric between 0 and $T-1$. At date T, the shock materializes in one-country which implies $\theta_{A,t} \neq \theta_{B,t}$. The duplication argument cannot therefore apply any longer.

We now prove the uniqueness of this solution.

Assume that another solution $\left(\hat{K}_{A,t}, \hat{H}_{A,t}, \hat{C}_{A,t}, \hat{K}_{B,t}, \hat{H}_{B,t}, \hat{C}_{B,t}, \hat{K}_{t+1}, \hat{\lambda}_t, \hat{\nu}_t\right)$ exists, given the initial per capita stock of world capital $\hat{K}_0$. By definition, this allocation is such that at date 0

$$\hat{K}_1 = (1-\delta)\,\hat{K}_0 + \pi\left[F\left(\hat{K}_{A,0}, \hat{H}_{A,0};\theta_{A,0}\right) - \hat{C}_{A,0}\right] + (1-\pi)\left[F\left(\hat{K}_{B,0}, \hat{H}_{B,0};\theta_{B,0}\right) - \hat{C}_{B,0}\right] \tag{47}$$

$$\hat{K}_0 = \pi\,\hat{K}_{A,0} + (1-\pi)\,\hat{K}_{B,0} \tag{48}$$

$$\hat{\lambda}_0 = E_0\left[(1-\delta)\hat{\lambda}_1 + \hat{\nu}_1\right] \tag{49}$$

and for $J = A, B$

$$U_1\left(\hat{C}_{J,0}, 1 - \hat{H}_{J,0}\right) = \hat{\lambda}_0 \tag{50}$$

$$\frac{U_2\left(\hat{C}_{J,0}, 1 - \hat{H}_{J,0}\right)}{F_2\left(\hat{K}_{J,0}, \hat{H}_{J,0}; \theta_{J,0}\right)} = \hat{\lambda}_0 \tag{51}$$

$$F_1\left(\hat{K}_{J,0}, \hat{H}_{J,0}; \theta_{J,0}\right) = \frac{\hat{\nu}_0}{\hat{\lambda}_0} \tag{52}$$

Out of this solution, we can construct two distinct autarkic equilibrium allocations for countries A and B. To begin with, affect $\hat{K}_{A,0}$ units of capital per capita to economy A and $\hat{K}_{B,0}$ to economy B. Condition (48) ensures that this split of the initial world stock of capital $\hat{K}_0$ is feasible. Assume that each economy uses all available capital. Using equations (49) to (52), we see that both vectors $\left(\hat{K}_{A,0}, \hat{H}_{A,0}, \hat{C}_{A,0}, \hat{\lambda}_0, \hat{\nu}_0\right)$ and $\left(\hat{K}_{B,0}, \hat{H}_{B,0}, \hat{B}_{A,0}, \hat{\lambda}_0, \hat{\nu}_0\right)$ satisfy conditions (8) to (12). Finally, capital accumulated in the two autarkic economies, $(1-\delta)\hat{K}_{A,0} + F\left(\hat{K}_{A,0}, \hat{H}_{A,0}; \theta_{A,0}\right) - \hat{C}_{A,0}$ and $(1-\delta)\hat{K}_{B,0} + F\left(\hat{K}_{B,0}, \hat{H}_{B,0}; \theta_{B,0}\right) - \hat{C}_{B,0}$, add up to $\hat{K}_1$, according to (47) and (48). No reallocation of capital is necessary at the beginning of period 1, meaning that this allocation of the two-country economy is indeed the juxtaposition of two autarkic economies.

We have therefore constructed two solutions of the single-country problem (7) to (12). Assumption (A) therefore implies that these solutions are identical to the first solution constructed

$$\left\{\begin{array}{rcl} \hat{K}_{A,t} & = & \hat{K}_{B,t} = \mathcal{K}_t^{ce} \\ \hat{H}_{A,t} & = & \hat{H}_{B,t} = H_t^{ce} \\ \hat{C}_{A,t} & = & \hat{C}_{B,t} = C_t^{ce} \\ (1-\delta)\hat{K}_{A,0} + F\left(\hat{K}_{A,0}, \hat{H}_{A,0}; \theta_{A,0}\right) - \hat{C}_{A,0} & = & (1-\delta)\hat{K}_{B,0} + F\left(\hat{K}_{B,0}, \hat{H}_{B,0}; \theta_{B,0}\right) - \hat{C}_{B,0} = K_{t+1}^{ce} \\ \hat{\lambda}_t & = & \lambda_t^{ce} \\ \hat{\nu}_t & = & \nu_t^{ce} \end{array}\right.$$

In other words, there exists a unique solution and this solution is symmetrical.