W – 18

june 2008

WORKING PAPERS

Ivo Krznar

International Business Cycles with Frictions in Goods and Factors Markets

CROATIAN NATIONAL BANK

International Business Cycles with Frictions in Goods and Factors Markets

Ivo Krznar
ivo.krznar@hnb.hr

The views expressed in this paper are not necessarily the views of the Croatian National Bank.

June 2008

CROATIAN NATIONAL BANK

Publisher:
Croatian National Bank
Publishing Department
Trg hrvatskih velikana 3, 10002 Zagreb
Phone: 385-1-4564-555
Contact phone: 385-1-4565-006
Fax: 385-1-4564-687

Website:
http://www.hnb.hr

Printed by:
Kratis d.o.o., Zagreb

Printed in 350 copies

ISSN 1331–8586

International Business Cycles with Frictions in Goods and Factors Markets

Ivo Krznar

Abstract

This paper explores the impact of frictions in the market for final goods and factors of production on international transmission of business cycles. In particular, I analyze the role of habits in consumption, capital adjustment costs and labor market frictions in the form of habits in leisure or labor adjustment costs, in a standard international real business cycles model with complete markets. Overall, these frictions that help explain many salient facts of a closed-economy have less success in resolving international comovement puzzles. Specifically, I find that capital adjustment costs together with consumption habits help explain positive investment comovement only – in combination with capital adjustment costs, consumption habits provide a channel through which capital adjustment costs become larger than the opportunity costs of not investing in a more productive country. However, resolving the investment puzzle comes at the expense of aggravating other comovement problems. In addition, I find that frictions in the labor market do not help to explain factor comovements such as the employment and investment puzzle. Furthermore, while both labor adjustment costs and leisure habits increase the output correlation, only the effects of the latter present forces toward resolving the consumption cross-correlation puzzle (although not actually resolving it). This mainly comes as a result of leisure habits reducing the consumption correlation through amplified effects on the nonseparability of consumption and leisure.

JEL: E32, G12, G15, D90

Keywords: international real business cycles, risk sharing, habit formation preferences, adjustment costs

I am grateful to Jordi Caballe, Juan Carlos Conesa, Alexandre Dmitriev and Evan Kraft for all the discussions and useful comments. Ministerio de Educación y Ciencia under the FPU grant is gratefully acknowledged. All remaining errors are mine.

Contents

1 Introduction

In a closed economy environment, real business cycle (RBC) theory has enjoyed a measure of success in accounting for many business cycle features. However, most of the poor matching performance of the standard RBC model came from the weakness of its internal propagation mechanism. During the past decade, several studies extended the standard RBC model to address this difficulty. The extensions were made via the introduction of different frictions in domestic markets for goods and factors of production. In particular, labor market frictions such as labor adjustment costs (Cogley and Nason (1995), Janko (2008) and Chang et al. (2006)), habit preferences over leisure (Bouakez and Kano (2006), Wen (1998), Hotz et al. (1988) and Eichenbaum et al. (1988)) or the combination of habit preferences over consumption and capital adjustment costs (Boldrin et al. (2001), Beaubrun and Tripier (2005) and Christiano et al. (2005)) turned out to be important in magnifying the propagation of shocks in the economy. Not only do these frictions improve the matching performance of the standard RBC model, but they are now being used to understand a wide range of issues in asset pricing, growth, monetary and international economics.[1]

However, closed-economy models abstract from the fact that countries participate in international markets. In particular, they ignore that countries can have the opportunity to share country-specific risks with other countries through the exchange of goods and financial assets. An early open-economy version of the standard RBC model (international real business cycles model, henceforth IRBC model) that incorporated international linkages has been less successful than its closed-economy counterpart in replicating the basic characteristics of international comovements of output, consumption, investment and employment.[2] This model assumes the existence of complete markets that in turn implies perfect risk sharing among agents in the world economy. Perfect risk sharing has implications that are far away from the data. First, empirical cross-correlation of consumption is generally similar to cross-country correlation of output, whereas the standard IRBC model with complete markets produces consumption correlation that is much higher than that of output (consumption puzzle). And second, investment and employment tend to be positively correlated across the countries, whereas the model predicts a negative correlation (investment and employment puzzle).

To reconcile data and theory, models were developed in which risk-sharing is

1 Several papers are worth mentioning. Carroll et al. (2000) suggest that consumption habits may be able to explain the relationship between savings and growth across countries. Fuhrer (2000) argues that consumption habits can induce hump-shaped responses of consumption and inflation to monetary shocks. Mendoza (1991) finds that introducing leisure habits in a small open-economy RBC model improves the fit of consumption and trade balance. Boldrin et al. (2001) show that the combination of consumption habits, capital adjustment costs and labor adjustment costs helps to account for the equity premium puzzle in the full-blown general equilibrium model. Janko (2008) finds that labor adjustment costs are one of the factors that are crucial in explaining business cycle properties of real as well as nominal variables.

2 See, for example, Backus et al. (1992).

limited because of domestic or international financial frictions.[3] While much of the IRBC literature focuses on financial frictions for resolving international comovement puzzles, this paper explores the role of frictions on markets for domestic goods and factors, which today present an important part of the closed-economy RBC model, on international comovements. In other words, I am asking the same question that Backus et al. (1992) put forward: what are the effects of extending the standard RBC model to an open-economy environment. However, since from the time the Backus et al. (1992) paper was published, much effort has been devoted to extending the standard RBC model and trying to replicate salient features of the closed-economy business cycle. In order to explore the effect of goods and factors market frictions that represented those extensions on international comovements, I build a two-country IRBC model with habit formation preferences over consumption and adjustment costs on capital change in a complete markets environment. In this setting individuals have complete access to international risk-sharing (perfect risk sharing). In addition to consumption habits and capital adjustment costs, I analyze the impact of two labor market frictions – demand-side friction in the form of habit formation preferences over leisure and supply-side friction in the form of labor adjustment costs.

The main message of this paper is that the "real" frictions that help explain many closed-economy features resolve only the investment comovement puzzle. In particular, I find that capital adjustment costs together with consumption habits help to resolve the investment comovement puzzle by impairing capital flows. Frictions on the labor market do not help explain factor comovements like the employment and investment puzzle. On the other hand, both labor adjustment costs and leisure habits increase the output correlation. However, only the effects of the latter work towards resolution of the consumption cross-correlation puzzle (although not actually resolving it). This mainly comes as a result of leisure habits reducing consumption correlation through amplified effects on nonseparability between consumption and leisure. On the whole, real frictions, either when resolving the investment puzzle or trying to resolve the consumption puzzle, accentuate problems in explaining other international comovements.

The rest of the paper is organized as follows. In Section 2 I present a two-country IRBC model where habits and adjustment costs are incorporated in a complete markets environment. Simulation results together with interpretation of the results in terms of domestic and international (co)movements are presented in Section 3. Section 4 concludes. Appendix shows how to decentralize the social

3 Baxter and Crucini (1995) and Kollmann (1996) investigated the quantitative impact of elimination of trade in state-contingent assets on the properties of international real business cycles. They found that the exogenous limit on the assets that may be traded was not severe enough in terms of risk sharing, investment flows and working effort to resolve correlation puzzles. Kehoe and Perri (2002) examined the model in which limited risk sharing arises endogenously from the limited ability to enforce international credit arrangements between countries. They find that this contract enforcement friction goes a long way in reconciling the IRBC theory and data (although not all the way in terms of the consumption puzzle). Recently, Yakhin (2007) show that exogenous market incompleteness can also generate positive employment and investment cross-correlations once additional nominal rigidities are introduced (staggered wages and monopolistic behavior of households with respect to supply of labor).

planner's problem. Finally, in the second part of the Appendix, I describe in detail the algorithm that was constructed to solve and simulate the model.

2 The Model Economy

The model considered here follows closely the structure of earlier two-country IRBC models with complete markets (see, in particular, the model by Backus et al. (1992) or Baxter and Crucini (1995)) except here a number of frictions in goods and factors markets are incorporated: habit formation preferences over consumption and leisure and adjustment costs on change of capital and on change of labor. In this section, I first describe the international environment of the model. Then I present a model as social planner's problem. In the same subsection I provide and interpret the optimality conditions the solution of which the social planner has to satisfy and that I will use in order to simulate the same solution in the next section.

2.1 The Environment

The world economy consists of two countries indexed by $j=1,2$, each populated with a continuum of identical households. Households in country j have preferences over consumption, c_{jt}, past consumption incorporated in consumption habit stock, h_{jt}^{c},[4] and labor, l_{jt}, represented by the Von-Neumann Morgenstern expected utility function. Consumption habit stock evolves through the standard law of motion characterized by a persistency parameter, λ^{c}.

I also allow for two labor market frictions and analyze their impact separately – demand-side friction in the form of leisure habits and supply-side friction in the form of labor adjustment costs. However, for the sake of compactness I will present the model as if both labor market frictions are being analyzed at the same time. By shutting down the parameter characterizing each labor market friction, the model could be rewritten to incorporate each labor market friction separately.

When I allow for demand-side friction in the labor market, households also have preferences over past labor incorporated in leisure habit stock, h_{jt}^{l}. Leisure habit stock evolves through standard law of motion characterized by persistency parameters, λ^{l}. In this case, firms decide on labor they want to hire, l_{jt}, and investment, i_{jt}. Firm's capital accumulation technology is subject to capital adjustment costs governed by the function $\phi(\cdot)$.

On the other hand, when I introduce supply-side friction in the labor market, firms decide on new hirings, m_{jt}, in addition to the investment decision, which is subject to adjustment costs. Productive employment at time $t+1$ is hired at time t. In deciding about new hirings, firms take into account that on each occasion labor hours differ across periods they will face labor adjustment costs, governed

4 The particular specification of preferences that I adopt links the household's habits to its own past consumption ("internal habit"), rather than aggregate, economy-wide consumption ("external habit").

by the function $g(\cdot)$. Furthermore, in each period, exogenous destruction of hours worked occurs by the "quit" rate $\psi \in (0,1)$. Hence, changing employment within the firm is costly, but it is costless to hire or replace the amount of employment that was exogenously wiped out.

There is a single homogeneous good produced, consumed and used for investment by both countries. A country's j output is produced using the technology that exhibits constant return to scale using capital, k_{jt} and labor, l_{jt} and is subject to country-specific labor augmenting total factor productivity shock, z_{jt}. The two countries are symmetric i.e. they share the same structure of economy in terms of preference, technology forms and parameters. The countries differ in two important aspects. In the first, labor input consists only of domestic labor (labor does not move across the borders). And in the second, production is subject to a country-specific (labor augmenting) technology shock.

2.2 The Social Planner Problem

I characterize the equilibrium in the world economy by exploiting the equivalence between competitive equilibrium and Pareto optimum with reference to the second welfare theorem[5] (in the Appendix I show how to decentralize the social planner's problem). Consequently, the equilibrium allocation in this economy can be computed as the solution to the social planner's problem. The social planner chooses contingency plans for $\left\{c_{jt}, x_{jt}, i_{jt}\right\}_{t=0}^{\infty}$ in order to maximize the expected discounted sum of weighted utilities of the two countries $j=\{1,2\}$. The control variable, x_{jt}, denotes new hirings, m_{jt}, in the case of analyzing supply-side labor market friction – labor adjustment costs, or just labor decision, l_{jt}, in the case of examining demand-side labor market friction – leisure habits. The expectation is taken over the sequence of the shocks $\left\{z_t\right\}_{t=0}^{\infty}$ where $z_t=(z_{1t}, z_{2t})$.

I will present the model in "continuous" formulations in order to be consistent with the algorithm I use to solve the model – the algorithm utilizes a shock process that has continuous support. To do this, I first introduce some technicalities concerning the formal representation of uncertainty.

Let $(Z, \mathcal{Z})$ be a measurable space, where $\mathcal{Z}$ is a σ–algebra of the Borel subsets of Z. Then the transition function can be defined as $Q : Z \times \mathcal{Z} \rightarrow [0,1]$ on $(Z, \mathcal{Z})$. It is assumed that the transition function satisfies the Feller property. The sequence of the exogenous random vector $\{z_t\}$ is a Markov process generated by Q. Then, for a given point $z \in Z$ and a set $A \subset \mathcal{Z}$, $Q(z, A)$ can be interpreted as a probability that the next period's shock lies in A, given that the current shock is z.

Next, I define the spaces for the partial histories of shocks $z^t=(z_1, z_2, \ldots, z_t)$ for $t=1,2,\ldots$ Given a measurable space $(Z, \mathcal{Z})$ a t–fold product space $(Z^t, \mathcal{Z}^t)$ can be defined as

$$(Z^t, \mathcal{Z}^t)=(Z \times \ldots \times Z, \sigma(Z \times \ldots \times \mathcal{Z})), \qquad (t \text{ times}) \tag{1}$$

5 Note that this is possible since, among other things, I am dealing with internal habits that, in comparison to external, do not exert any externality. For details see Alvarez et al. (2004) or Alonso et al. (2004).

where $\sigma(Z \times ... \times \mathcal{Z})$ denotes σ–algebra generated by the product σ–algebras, for any finite $t=1,2,...$ It follows that, for any given initial value of the shock $z_0 \in Z$, and the transition function Q on $(Z, \mathcal{Z})$, the probability measures $\mu^t(z_0, \cdot) : \mathcal{Z}^t \to [0,1]$ can be defined on these spaces.[6] For any rectangle $B=A_1\times ... \times A_t \in \mathcal{Z}^t$, let

$$\mu^t(z_0, B) = \int_{A_1} \cdots \int_{A_{t-1}} \int_{A_t} Q(z_{t-1}, dz_t) Q(z_{t-2}, dz_{t-1}) ... Q(z_0, dz_1). \qquad (2)$$

In this economy, a consumption allocation, for both $j=\{1,2\}$, is then defined as a sequence of $\{c_{jt}\}_{t=0}^{\infty}$ where $c_{jt} : Z^t \to \mathbb{R}_+$ is a $\mathcal{Z}^t$ – measurable function, for all t. In a similar way, allocations of investment and labor supply, or new hirings are defined as sequences of $\{i_{jt}\}_{t=0}^{\infty}$, $\{l_{jt}\}_{t=0}^{\infty}$ or $\{m_{jt}\}_{t=0}^{\infty}$ respectively, where $i_{jt} : Z^t \to \mathbb{R}_+$, $l_{jt} : Z^t \to (0,1)$ and $m_{jt} : Z^t \to (0,1)$ are $\mathcal{Z}^t$ – measurable functions, for all t.

Then the objective of the planner is to solve the following problem:

$$\max_{\{c_{jt}, x_{jt}, i_{jt}\}_{t=0}^{\infty}} \sum_{t=0}^{\infty} \beta^t \int_{Z^t} \left[\sum_{j=1}^{2} \lambda_j u\left(c_{jt}, h_{jt}^c, l_{jt}, h_{jt}^l\right) \right] \mu^t(z_0, dz^t) \qquad (3)$$

subject to:

$$\sum_{j=1}^{2} c_{jt} + \sum_{j=1}^{2} i_{jt} = \sum_{j=1}^{2} \left[f\left(k_{jt}, l_{jt}, z_{jt}\right) - g\left(m_{jt}, l_{jt}\right) \right], \qquad (4)$$

$$k_{jt+1} = (1-\delta) k_{jt} + \phi\left(\frac{i_{jt}}{k_{jt}}\right) k_{jt}, \qquad 0 \le \delta \le 1 \qquad (5)$$

$$h_{jt+1}^c = h_{jt}^c + \lambda^c \left(c_{jt} - h_{jt}^c\right), \qquad 0 \le \lambda^c \le 1 \qquad (6)$$

in the case of labor adjustment costs:

$$l_{jt+1} = (1-\psi) l_{jt} + m_{jt}, \qquad 0 \le \psi \le 1 \qquad (7)$$

with

k_{j0}, h_{j0}^c, z_{j0}, and l_{j0} given, for $j=\{1,2\}$

or in the case of leisure habits:

$$h_{jt+1}^l = h_{jt}^l + \lambda^l \left(1 - l_{jt} - h_{jt}^l\right), \qquad 0 \le \lambda^l \le 1 \qquad (8)$$

with

k_{j0}, h_{j0}^c, z_{j0} and h_{j0}^l given, for $j=\{1,2\}$

6 As shown in Stokey and Lucas (1989) it is sufficient to define $\mu^t(z_0, \cdot)$ over the measurable rectangles in Z^t.

Parameters λ_j for $j=\{1,2\}$ represent the weights that the planner attaches to each country. Furthermore, $u(\cdot)$ represents a utility function that is assumed to be bounded, continuous, strictly concave, strictly increasing and satisfies Inada conditions. $f(\cdot)$ is a production function satisfying concavity and differentiability properties.

To find first order conditions corresponding to the planner's problem, I rewrite the consumption habit stock as a function of all past consumptions:

$$h^c_{jt+1} = h^c_{jt} + \lambda^c\left(c_{jt} - h^c_{jt}\right) = \lambda^c \sum_{i=0}^{\infty}\left(1-\lambda^c\right)^i c_{jt-i} \tag{9}$$

and the leisure habit stock as a function of all past leisure hours:

$$h^l_{jt+1} = h^l_{jt} + \lambda^l\left(1 - l_{jt} - h^l_{jt}\right) = \lambda^l \sum_{i=0}^{\infty}\left(1-\lambda^l\right)^i \left(1 - l_{jt-i}\right) \tag{10}$$

Furthermore, I implicitly define the investment function as

$$I\left(k_{jt+1}, k_{jt}\right) = \phi_i^{-1}\left(\frac{k_{jt+1} - (1-\delta)k_{jt}}{k_{jt}}\right)k_{jt} \tag{11}$$

Then the optimality conditions that a solution of the planner's problem has to satisfy are the following.

The Euler equation for $j=\{1,2\}$ reads as:

$$\begin{aligned}&\left\{u_1\left(c_{jt}, h^c_{jt}, l_{jt}, h^l_{jt}\right) + \beta\lambda^c \int_Z \left[\sum_{i=0}^{\infty}\beta^i\left(1-\lambda^c\right)^i u_2\left(c_{jt+i+1}, h^c_{jt+i+1}, l_{jt+i+1}, h^l_{jt+i+1}\right)\right] Q\left(z_t, dz_{t+1}\right)\right\}\times \\ &\times I_1\left(k_{jt+1}, k_{jt}\right) = \beta\int_Z\left[\left(f_1\left(k_{jt+1}, l_{jt+1}, z_{jt+1}\right) + I_2\left(k_{jt+2}, k_{jt+1}\right)\right)\times\right. \\ &\times\left.\left(u_1\left(c_{jt+1}, h^c_{jt+1}, l_{jt+1}, h^l_{jt+1}\right) + \beta\lambda^c\sum_{i=0}^{\infty}\beta^i\left(1-\lambda^c\right)^i u_2\left(c_{jt+i+2}, h^c_{jt+i+2}, l_{jt+i+2}, h^l_{jt+i+2}\right)\right)\right] Q\left(z_t, dz_{t+1}\right)\end{aligned} \tag{12}$$

The labor supply equation is given by:

$$\begin{aligned}&g_m\left(m_{jt}, l_{jt}\right)\times \\ &\left\{u_1\left(c_{jt}, h^c_{jt}, l_{jt}, h^l_{jt}\right) + \beta\lambda^c\int_Z\left[\sum_{i=0}^{\infty}\beta^i\left(1-\lambda^c\right)^i u_2\left(c_{jt+i+1}, h^c_{jt+i+1}, l_{jt+i+1}, h^l_{jt+i+1}\right)\right]Q\left(z_t, dz_{t+1}\right)\right\} = \\ &\beta\left\{\int_Z\left[u_3\left(c_{jt+1}, h_{jt+1}, l_{jt+1}\right) + \beta\lambda^l\sum_{i=0}^{\infty}\beta^i\left(1-\lambda^l\right)^i u_4\left(c_{jt+i+2}, h^c_{jt+i+2}, l_{jt+i+2}, h^l_{jt+i+2}\right) + \right.\right. \\ &\left[u_1\left(c_{jt+1}, h^c_{jt+1}, l_{jt+1}, h^l_{jt+1}\right) + \beta\lambda^c\sum_{i=0}^{\infty}\beta^i\left(1-\lambda^c\right)^i u_2\left(c_{jt+i+2}, h^c_{jt+i+2}, l_{jt+i+2}, h^l_{jt+i+2}\right)\right]\times \\ &\left.\left.\left[f_2\left(k_{jt+1}, l_{jt+1}, z_{jt+1}\right) - g_l\left(m_{jt+1}, l_{jt+1}\right) + (1-\psi)g_m\left(m_{jt+1}, l_{jt+1}\right)\right]\right]Q\left(z_t, dz_{t+1}\right)\right\}\end{aligned} \tag{13}$$

Finally, the risk sharing condition reads as:

$$\frac{\left(u_1\left(c_{1t},h_{1t}^c,l_{1t},h_{1t}^l\right)+\beta\lambda^c\int_Z\left[\sum_{i=0}^{\infty}\beta^i\left(1-\lambda^c\right)^i u_2\left(c_{1t+i+1},h_{1t+i+1}^c,l_{1t+i+1},h_{1t+i+1}^l\right)\right]Q\left(z_t,dz_{t+1}\right)\right)}{\left(u_1\left(c_{2t},h_{2t}^c,l_{2t},h_{2t}^l\right)+\beta\lambda^c\int_Z\left[\sum_{i=0}^{\infty}\beta^i\left(1-\lambda^c\right)^i u_2\left(c_{2t+i+1},h_{2t+i+1}^c,l_{2t+i+1},h_{2t+i+1}^l\right)\right]Q\left(z_t,dz_{t+1}\right)\right)}=\frac{\lambda_2}{\lambda_1} \tag{14}$$

In those conditions $u_i(c_{jt}, h^c_{jt}, l_{jt}, h^l_{jt})$, $f_i(k_{jt}, l_{jt}, z_{jt})$, $I_i(k_{jt+1}, k_{jt})$, $g_i(m_{jt}, l_{jt})$ denote the partial derivative of the function $u(\cdot)$, $f(\cdot)$, $I(\cdot)$ and $g(\cdot)$ respectively, with the respect to the i–th component variable.

To sum up, in the optimum, the world economy can be described by the following optimality conditions: Euler equations (12) and labor supply equations (13) for both countries $j=\{1,2\}$ and risk sharing condition (14) together with the budget constraint (4), laws of motion for capital, consumption habit stock, leisure habit stock (in case of examining demand-side friction in the labor market) or hours worked (in case of analyzing supply-side friction in the labor market) given in (5), (6), (7) and (8) respectively in each country.

The optimality conditions that match up to the social planner's problem help shed some light on the planner's intratemporal and intertemporal allocation decisions. They demonstrate the dynamic characteristics of consumption, employment and capital in a framework with frictions in labor, capital and goods market. In particular, for each country the Euler equation represents the planner's intertemporal consumption trade-off: if the planner saves and invests one additional unit of the final good instead of consuming it today, she will consume more tomorrow as a result of higher capital stock to work with. But since the present utility of the planner is derived from past consumption also, which means that agents dislike variations in habit-adjusted consumption, rather than in consumption itself, reducing consumption today will come at the utility cost of $u_1(c_{jt}, h^c_{jt}, l_{jt}, h^l_{jt})$, but also at the expected discounted utility benefit of $\beta\lambda^c\int_Z\left[\sum_{i=0}^{\infty}\left(1-\lambda^c\right)^i u_2\left(c_{jt+i+1},h_{jt+i+1}^c,l_{jt+i+1},h_{jt+i+1}^l\right)\right]Q\left(z_t,dz_{t+1}\right)$. Furthermore, one unit of final good saved today will not translate to a proportional increase of capital stock because capital is subject to capital adjustment costs (having a cost of $I_1(k_{jt+1}, k_{jt})$) and to depreciation (represented by the cost of $I_2(k_{jt+2}, k_{jt+1})$). Each additional unit of production tomorrow, when used for consumption, will yield utility benefit coming from decreased consumption today but also utility loss because of habit forming preferences. The labor-supply equation shows planner's intratemporal and intertemporal decisions on labor supply (leisure) and consumption in the general model with consumption and leisure habits and labor and capital adjustment costs. Since I am analyzing supply-side friction (leisure habits) and demand-side friction (labor adjustment costs) separately I will interpret the labor-supply equation by assuming that just one of the frictions is present. Hence, if I allow only for labor adjustment costs (implying that utility is not derived from past leisure decisions), reducing new hirings today will come at the expense of labor adjustment costs, which will have both utility benefit and utility cost. This opposite effect on utility is the result of consumption habits, as in the Euler equation. Since labor hired today becomes productive only tomorrow, a fall in new hirings today will result in an expected discounted utility gain from increased leisure tomorrow. On the other hand, less hiring today will decrease productive labor stock tomorrow, part of which will be destroyed. A smaller labor stock tomorrow will produce less. This will again have a utility loss from present consumption and discounted expected utility benefit from the future stream of consumption. If only leisure habits are present (and I neglect labor adjustment costs i.e. $g(m_{jt}, l_{jt}) = 0$) then labor employed today becomes productive immediately. Hence, reducing labor supply today will create a utility gain coming from increasing leisure activities today. On the other hand, this will come at the expected discounted utility loss coming from the future stream of leisure. Furthermore, a reduced labor force will produce fewer final goods which, when used for consumption, have again a utility loss from present consumption and a utility benefit coming from the future stream of consumption. Finally, the risk-sharing equation requires that the ratio of marginal utilities of consumption in both countries has to be equal to the ratio of weights that the planner assigns to each country.

3 Quantitative Model Prediction

To explore the quantitative impact of different frictions for international comovements, the model has to be calibrated and functional forms have to be chosen. Before analyzing economies with frictions, it is useful to review the mechanics of a frictionless model (benchmark perfect risk sharing model) in order to understand the puzzles in the first place. I start by choosing the benchmark economy that is essentially a version of Backus et al. (1992), which has become the standard in the literature as a perfect risk-sharing case plagued with international comovement puzzles. I describe the calibration of the benchmark model in subsection 3.1 and that of the model with different frictions in subsection 3.2. For the sake of comparability, when calibrating the model I build on the existing IRBC studies that take parameter values from growth observations or micro studies. If parameter value cannot be pinned down from the data, I choose its value such that the model's second moment of some particular variable matches its empirical counterpart. If this is not possible, I adapt the parameter's value from existing studies and then run the sensitivity analysis by varying the value of this particular parameter. The calibration procedure is summarized in Table 1.

In this section I also briefly discuss the numerical algorithm that I construct for simulating the solution that satisfies the optimality conditions given in the previous section. In the end I provide the model's findings and sensitivity analyses results from a simulation exercise.

3.1 Functional Forms and Calibration of the Benchmark Model

As mentioned before, the world in my model is composed of two equally sized countries with identical preferences and technology and the same initial endowments so that the planner's weights are the same, $\lambda_1 = \lambda_2$. Following the previous IRBC literature I choose the functional forms of preferences and technology (and the set of parameters values associated with these forms) to match the characteristics of the long-run behavior of aggregates observed in the U.S. data (for both $j=\{1,2\}$).

3.1.1 Technology Parameters

I use Cobb-Douglas production function

$$F(k_{jt}, l_{jt}, z_{jt}) = k_{jt}^{\alpha}(z_{jt}l_{jt})^{1-\alpha} \tag{15}$$

which is consistent with the stability of labor share in output despite secular increases in the real wage. The parameter α represents the share of capital in output and z_{jt} denotes country-specific, labor augmenting total factor productivity (TFP) shock.

The stochastic fluctuations of the TFP shocks of the two countries $z_t=(z_{1t}, z_{2t})$ are assumed to follow a first order vector-autoregressive process, $VAR(1)$ in logs. Letting $Z_{t+1} = (\log(z_{1t+1}), \log(z_{2t+1}))'$ the $VAR(1)$ reads as:[7]

$$Z_{t+1} = RZ_t + \varepsilon_{t+1} \tag{16}$$

where $\{\varepsilon_t\}_{t=0}^{\infty}$ is a sequence of bivariate normal random variables with zero mean and variance-covariance matrix Ω and where R is a autoregressive coefficient matrix.

In general, TFP shocks can be related through the non-zero off-diagonal coefficient of the matrix R and non-zero off-diagonal element of the covariance matrix Ω. In parametrizing the coefficient matrix R, I follow Baxter and Crucini (1995), Kollmann (1996) and Heathcote and Perri (2002) who found little evidence of spillovers between the United States and some European countries. Furthermore, as is common in the real business cycle literature I assume that each shock is highly auto-correlated. I summarize the parameters of the process given in (16) by:

$$R = \begin{bmatrix} 0.95 & 0 \\ 0 & 0.95 \end{bmatrix}, \quad \Omega = 0.007^2 \begin{bmatrix} 1 & 0.25 \\ 0.25 & 1 \end{bmatrix} \tag{17}$$

The later is consistent with the estimation results of TFP shock-processes for the United States and Europe.[8]

The law of motion of the capital stock (5) in the steady state was used to calibrate the depreciation rate, δ, which depends on the investment/capital ratio that I restrict from observed data to take the value of 0.025 (as in Cooley (1995) I assume that the investment/output share in the US data is roughly 0.25, and that capital output ratio on a quarterly basis is around 10)

7 The transition function Q on $(Z, \mathcal{Z})$ can be then defined implicitly by the assumption that the random shocks follow the stochastic difference equation (16). See Theorem 8.9 in Stokey and Lucas (1989), which insures that a first order stochastic difference equation can be used to define a transition function.

8 See Backus et al. (1992), Baxter and Crucini (1995), Kollmann (1996) and Heathcote and Perri (2002).

$$k_{ss} = \delta i_{ss} \tag{18}$$

where subscript *ss* denotes the value of the corresponding variable in the steady state.[9] Hence $\delta = 0.025$.

The range of estimates for the capital share in the literature is $\alpha \in [0.25, 4]$. I choose a compromise and set $\alpha = 0.36$ reflecting a long-run labor share in national income accounts of 2/3.

3.1.2 Preference Parameters

In the benchmark model economy, the preferences are of constant relative risk aversion form:

$$u\left(c_{jt}, l_{jt}\right) = \frac{\left[c_{jt}^{\ \gamma}\left(1 - l_{jt}\right)^{1-\gamma}\right]^{1-\sigma} - 1}{1 - \sigma} \tag{19}$$

where σ represents the curvature on utility, while γ denotes the share of consumption (relative to leisure) in a composite consumer good.

The discount rate, β, was set so as to match the net average interest rate, $(r-\delta)$ in the US data of 6.5% (annual base). Using the Euler equation (12) in the deterministic steady state and shutting down all frictions I have

$$\frac{1}{\beta} = \left[1 + \left(\alpha k_{ss}^{\alpha-1} l_{ss}^{1-\alpha} - \delta\right)\right]^{\frac{1}{4}} = \left[1 + (r - \delta)\right]^{\frac{1}{4}} \tag{20}$$

so that $\beta = 0.984$.

The share of consumption good in the composite good, γ, was pinned down from the labor supply equation (13) in the deterministic steady state by shutting down all the frictions and assuming that time devoted to market activities is equal to 1/3 and that the investment/output share is equal to 0.25. In the steady state the labor supply equation (13) reads as:

$$c_{ss} = \frac{\gamma\left(1 - l_{ss}\right)(1 - \alpha) k_{ss}^{\alpha} l_{ss}^{-\alpha}}{(1 - \gamma)} \tag{21}$$

or by defining $c_{ss} = y_{ss} - i_{ss}$ and dividing by y I have

$$1 - \frac{i_{ss}}{y_{ss}} = \frac{\gamma\left(1 - l_{ss}\right)(1 - \alpha)}{l_{ss}(1 - \gamma)} \tag{22}$$

from which I get $\gamma = 0.369$.

I calibrate the utility curvature parameter, σ, such that the intertemporal elasticity of consumption, $IES(c_{jt}, c_{jt+1})$ in a deterministic model without any frictions given as

$$IES\left(c_{jt}, c_{jt+1}\right) = \frac{1}{1 - \gamma(1 - \sigma)} \tag{23}$$

9 Since I choose the same parametrization for both countries, they have the same deterministic steady state.

is equal to 1/2. This value corresponds to the value of the curvature equal to 2 which is usually assumed in RBC and IRBC literature concerned with models without endogenous labor supply. Holding constant intertemporal elasticity of substitution and having calculated γ, I can pin down the curvature parameter, $\sigma = 3.7$, corresponding to intertemporal elasticity of substitution of consumption equal to 1/2.

3.2 Calibration of the Model with Frictions

Once I have calibrated a benchmark model economy that does not include any friction, I present the calibration of a model with four different frictions. Unfortunately, it was only possible to calibrate the capital adjustment cost parameter "properly" (such that the model's investment volatility is equal to its empirical counterpart). In calibrating the parameters corresponding to other frictions, I adapt their values from studies related to mine. In the sensitivity analysis I allow for these parameters to take different values in exploring how changes of these values affect international comovements.

3.2.1 Capital Adjustment Costs

I use the specification in Jermann (1998) to deal with adjustment costs to change of capital. Adjustment costs are governed by the function $\phi\left(\frac{i_{jt}}{k_{jt}}\right)$ where $\phi(\cdot)$ is a positive, convex function given by:

$$\phi\left(\frac{i_{jt}}{k_{jt}}\right) = \frac{d_1}{1-\frac{1}{\xi}}\left(\frac{i_{jt}}{k_{jt}}\right)^{1-\frac{1}{\xi}} + d_2 \tag{24}$$

Parameter ξ represents the elasticity of investment with respect to Tobin's q (ratio of the price of a newly installed unit of capital to the price of investment good[10]). This parameter determines the magnitude of capital adjustment costs. Values for d_1 and d_2 are chosen so that the deterministic steady state is invariant to ξ[11] i.e. so that the steady state value of Tobin's q is equal to one. If $\xi \to \infty$ the capital accumulation formula reduces to the standard law of motion of capital without adjustment costs. I set the value for ξ so that the investment volatility in the model is similar to that in the data.

3.2.2 Labor Adjustment Costs

In the case of analyzing supply-side friction on labor market, labor adjustment costs follow the standard quadratic specification as suggested by Cogley and Nason (1995), Cooper et al. (2003) and Shapiro (1986):

10 Note that in the model without adjustment costs Tobin's q is equal to one.

11 The formulas are

$$d_1 = \delta^{\frac{1}{\xi}}$$
$$d_2 = \frac{1}{1-\xi}(1-\delta)$$

$$g\left(l_{jt}, m_{jt}\right) = \frac{\varphi}{2l_{jt}} \Delta l_{jt+1}^2 = \frac{\varphi}{2l_{jt}} \left(m_{jt} - \psi l_{jt}\right)^2 \tag{25}$$

where $\varphi \geq 0$ denotes labor adjustment cost parameter. When $\varphi > 0$, firms incur positive labor adjustment costs in terms of loss of their production if aggregate hours worked differ across periods. There will be no labor adjustment costs if $\varphi = 0$ or if hours worked do not fluctuate across periods (for example, in the deterministic steady state). A functional form of labor adjustment costs is homogeneous of degree one. Hence, decision on hirings does not depend on the number of firms, i.e. the assumption of a single representative firm holds. Furthermore, the labor adjustment cost function is convex and symmetric. Convexity of the labor adjustment cost function has the same interpretation as convexity of capital adjustment cost function – changing labor stock rapidly is more costly than changing it slowly. Furthermore, symmetric property of labor adjustment costs could be interpreted as it is as easy to hire workers as it is to fire them.[12] The micro foundation of this kind of friction on the labor market stems from the fact that labor adjustment costs are just a particular case of a two sided search-and-matching process in the labor market. In particular, my model with convex labor adjustment costs, if put in a closed-economy environment, would be a particular case of the RBC model with two sided search and matching in Merz (1995) if the elasticity of job matches with respect to total search effort were equal to zero, if a cost per unemployed worker is not incurred by varying search intensity and if posting a vacancy comes to an advertising cost that is governed by convex function.[13]

As is usual in the RBC literature, my model yields employment volatility lower than in the data. Hence, no calibration of the labor adjustment cost parameter as in the case of the capital adjustment cost parameter was possible. I set the labor adjustment cost parameter by referring to the labor adjustment costs literature. Cogley and Nason (1995) and Shapiro (1986) estimated a quadratic labor adjustment cost function similar to the one used here. Their findings correspond to the value of φ equal to 0.36. In a recent paper, Cooper et al. (2003) estimated a similar quadratic labor adjustment cost function, obtaining a value of φ around 2. Given that the study of Cooper et al. (2003) is more recent, I use this parameter value in simulating the model and in reporting my results. However, in order clearly to evaluate the impact of labor adjustment costs on international comovement, I conduct a sensitivity analysis with respect to φ, and consider values of $\varphi \in \{1,20\}$ as much smaller and much bigger value of labor adjustment cost parameter than the parameter value in the main simulation exercise.

The value of the quarterly exogenous quit rate is set to $\psi = 0.15$, based on micro evidence reported in Andolfatto (1996).

12 I also experimented with the natural assumption of being able to hire workers more easily than to fire them. Overall, the effect of asymmetric labor adjustment costs was very small. Furthermore, notice that there is no actual firing decision taking place. Employment is subject to continual exogenous depletion.

13 I am thankful for this comment to Thijs van Rens.

3.2.3 Consumption and Leisure Habits

I assume simple time additive non-persistent habit-in-consumption specification in the non-separable utility function[14] (between consumption and leisure) proposed by Constantinides (1990). Then $\lambda^c = 1$ in law of motion of consumption habit stock (6). In this case, consumption habit stock at period t is simply represented by the level of consumption at period $t-1$.

In dealing with leisure habits ($b^l \neq 0$, see below) I assume the same habit-in-leisure specification as for habit-in-consumption specification. Then $\lambda^l = 1$ in law of motion of leisure habit stock (8). This non-persistent specification of leisure habits found some support in empirical studies like Eichenbaum et al. (1988), Yun (1996) and Hotz et al. (1988).

Consequently, consumption and leisure habit stocks at period t are simply the levels of consumption and leisure at period $t-1$. Then the utility function reads as:

$$u\left(c_{jt}, h_{jt}^c, l_{jt}, h_{jt}^l\right) = u\left(c_{jt}, c_{jt-1}, l_{jt}, l_{jt-1}\right) = \frac{\left[\left(c_{jt} - b^c c_{jt-1}\right)^{\gamma}\left(1 - l_{jt} - b^l\left(1 - l_{jt-1}\right)\right)^{1-\gamma}\right]^{1-\sigma} - 1}{1-\sigma} \tag{26}$$

where b^c and b^l are consumption and leisure habit importance parameters. Now γ denotes the share of (habit adjusted) consumption (relative to (habit adjusted) leisure) in a composite consumer good.

Again, the share of consumption good in a composite good, γ, was pinned down from the labor supply equation (13) by assuming that time devoted to market activities is equal to 1/3 and that investment/output share is equal to 0.25. But now in the deterministic steady state the labor supply equation (13) with additive non-persistent consumption and leisure habits reads as:

$$1 - \frac{i_{ss}}{y_{ss}} = \frac{\gamma\left(1 - l_{ss} - b^l\left(1 - l_{ss}\right)\right)(1-\alpha)}{l_{ss}(1-\gamma)\left(1-b^c\right)\left(1-\beta b^l\right)} \times \left(1 - \beta b^c\right) \tag{27}$$

from which I get the value for γ depending on values for the habit importance parameters b^c and b^l.

Calibration of the habit model economy requires choosing a value for the habit importance parameter in consumption, b^c, and, in the case of analyzing the friction on the demand side of labor market, a value for the habit importance parameter in leisure, b^l. There are several studies that try to estimate the parameter of consumption and leisure habits (see Diaz et al. (2003) and Wen (1998) for an overview of the estimation of the consumption and leisure habit parameter, respectively). The conclusion of all these studies is that heterogeneity of data, techniques and goals in research rises to a very wide range of possible values for parameters b^c and b^l.

14 With additive habits the objective function of the planner preserves concavity property, whereas this might not be true in a model with multiplicative habits (see Alonso et al (2005) for details).

Ideally, I would be looking for an estimator consistent with my model in functional forms and length of period, which does not exist. The range of estimated or calibrated values of b^c and b^l in the literature is very wide. Studies of asset pricing,[15] found that consumption habits characterized by values in the range of 0.69 to 0.9 can help to explain the equity premium puzzle. Since those models are close to mine, in reporting my results I use a compromise between those values and set $b^c = 0.8$. Finally, as far as leisure habits are concerned I follow empirical literature[16] in parametrizing their importance parameter, $b^l = 0.7$. In sensitivity analysis I report the results from simulation of the model with different combinations of two values of habit importance parameters (with the values that should correspond to low and high values of the parameter), $b^c \in \{0.4, 0.8\}$ and $b^l \in \{0.4, 0.8\}$.

In the model with habits, again I calibrate the utility curvature parameter, σ, such that the intertemporal elasticity of consumption, $IES(c_{jt}, c_{jt+1})$[17] is equal to 1/2. In other words, I compare the benchmark economy and the economy with consumption and leisure habits but adjusted to have the same $IES(c_{jt}, c_{jt+1})$. This is achieved by changing the curvature parameter, σ. Holding the intertemporal elasticity of substitution constant and having calculated γ (depending on different values for b^c and b^l) I can pin down the curvature parameter, σ, which will now take different values for different values of b^c and b^l. Notice that in this way the steady state of the particular variable will be the same across different models and that simulated moments across different models will be comparable.

3.3 Numerical Solution of the Model

The social planner's problem was solved numerically using the parametrized expectations approach (PEA henceforth) introduced by Marcet (1989). The idea of PEA is to replace the expectation functions in (12), (13) and (14) by smooth parametric approximation functions of the current state variables[18] and a vector of parameters and then iterate on the values of parameters until rational expectation equilibrium is achieved. I choose PEA as a solution algorithm for two reasons. First, PEA circumvents the curse of dimensionality by avoiding the discretization of state space. And second, it has proven difficult to compute a solution of models that incorporate additive consumption habits by value function iteration algorithm, for example. Diaz et al. (2003) show that solving a simple growth model with exogenous incomplete markets and additive habits in consumption is not feasible. This is because the algorithm that relies on value function iteration cannot rule out

15 See Boldrin et al. (2001), Constantinides (1990) or Jermann (1998).

16 See Wen (1998), Hotz et al. (1988) and Eichenbaum et al. (1988).

17 Notice that since I deal with additive consumption habits recalibration of the coefficient of relative risk aversion in the model with habits is not needed since intertemporal elasticity of substitution of consumption in the model with habits is the same as in the setting without habits and it does not depend (in the deterministic steady state) on habit parameters b^c and λ^c. See Lemma 2 in Diaz et al. (2003) that establishes this result in the environment without labor. It is straightforward to show that the same lemma applies to my model with endogenous labor supply decision and leisure habits.

18 In my model the vector of states is given by $[k_{1t}, h^c_{1t}, y_{1t}, z_{1t}, k_{2t}, h^c_{2t}, y_{2t}, z_{2t}]$ where $h^c_{jt} = c_{jt-1}$ for $j = \{1,2\}$ and $y_{jt} = h^l_{jt} = 1 - l_{jt-1}$ in case of leisure habits or $y_{jt} = l_{jt}$ in case of studying labor adjustment costs.

ex ante the values of decision variables that the agent would try very hard to avoid (so that actually agents end up consuming negative habit adjusted consumption!). By the endogenous oversampling feature, PEA solves this problem. The endogenous oversampling feature implies that PEA only pays attention to those points that actually happen in the solution (for details see Marcet and Marshall (1994)) – only the economically relevant region of the state space is explored. For algorithm details see the Appendix.

3.4 Findings

In this section I compare the quantitative properties of the theoretical world economy with those of the data. I start with a brief discussion of international comovement puzzles by comparing simulation results of a standard, complete markets IRBC model without any friction on goods or factors markets (the benchmark, perfect risk sharing model) with the moments calculated from the data (Table 2). Then, I explore the quantitative effect of different frictions on international comovements. In particular, I analyze the simulation results of two models: a model with consumption habits, capital adjustment costs and labor adjustment costs and a model that instead of labor adjustment costs incorporates a different type of labor market friction, namely leisure habits.

First, I interpret the effects of introducing capital adjustment costs and consumption habits both separately and jointly on international comovements in comparison to results of the benchmark model and data. Then, I investigate separate consequences on international correlations of introducing labor adjustment costs, on the one hand, and leisure habits on the other in the model with consumption habits and capital adjustment costs. Table 2 shows simulation results of the model that incorporates consumption habits (represented by parameter b^c), capital adjustment costs and labor adjustment costs (represented by parameter φ). Table 3 shows the simulation results of the model that incorporates consumption habits (represented by parameter b^c), capital adjustment costs and leisure habits (represented by parameter b^l). By shutting down a particular parameter in two models, it is possible to explore separate effects of a particular friction on international comovements.

The statistics reported in all the tables in the first nine rows of the Data column are taken from Kehoe and Perri (2002) and pertain to the U.S. quarterly time series (logged and HP filtered with smoothing parameter 1600). International correlations in those tables are also taken from the same source and refer to the correlations between U.S. aggregate variables and the same variables for the aggregate of 15 European countries. The capital flow statistic was computed from the U.S. national accounts (NIPA) and pertains to the quarterly time series of net exports/GDP. To be consistent with the statistics computed from the data, the relevant model statistics are calculated from logged and HP filtered data with smoothing parameter 1600. Instead of simulating each model many times to obtain many samples of artificially generated short time series and then calculating the average throughout the samples and its standard deviations, I simulated each model just once, using however a long time series of each variable (10,000 periods).[19]

3.4.1 The Benchmark, Perfect Risk Sharing Model

In comparing the benchmark model and the data in the second and third columns of Table 2, we can see three international comovement puzzles documented in the literature. In the model, consumption cross-country correlation is substantially higher than that of output (0.65 vs. –0.02), while in the data the opposite is true (0.32 vs. 0.51). And both investment and employment correlations are negative in the model (–0.78 and –0.37 respectively) whereas in the data they are positive (0.29 and 0.43 respectively). In addition, there is one major discrepancy in the domestic economy – both net exports and investments are much more volatile in the model than in the data (0.81 vs. 0.15 and 6.04 vs. 3.24 respectively).

In order to get some intuition for the pattern of (co)movements of the model's aggregates and the dynamics of the model, I study impulse responses of a world economy to a 1% increase in total factor productivity in the home country[20] (pictured in Figure 1). All the impulse responses of the aggregates are measured as percentage deviations from their steady state values. Figure 1 illustrates what happens in the home and foreign country following a positive shock in the home country, which slowly dies out after the first period. Home investment and labor hours increase (resulting in an increase in domestic output) while foreign investment and employment fall (resulting in a fall in foreign output) – positive domestic productivity shock increases the productivity of capital and labor which results in a shift of resources to the home country. The capital stock in the home country increases both by domestic agents saving more and by more capital inflows from abroad taking advantage of higher return on capital in the home country. This will result in a negative cross-country correlation of investment. For our calibration of the model, investment rises much more than consumption and output together, leading to net exports deficit and negative correlation of net-exports and GDP. With regard to employment, the temporarily high productivity of labor induces home country agents to supply more labor since the substitution effect prevails over the wealth effect, while in the foreign country the stronger wealth effect of the shock generates a reduction in labor supply. This will result in a negative cross-country correlation of employment. Next, since country-specific risk is perfectly insured, agents in the home country agree to "share" some of the additional output generated by the increase in productivity in exchange for a similar deal when the other country receives a positive productivity shock. This will result in a positive cross-country correlation of consumption.[21] Finally, large volatility of investment and net exports

19 The two procedures should be equivalent assuming that number of simulations in the first and the sample size in the second procedure are large enough.

20 Notice that since there are no spillovers ($a_2 = 0$) the productivity in the foreign country does not change.

21 Note that consumption sharing between countries is not 1:1 because preferences are nonseparable in consumption and leisure making cross-country correlation of consumption smaller than 1. Actually, since consumption and labor are complements in utility function, consumption increases by more at home than abroad.

reflects the ability of agents in the model to costlessly shift investments across the countries (to a country which is more productive).

3.4.2 Adding capital adjustment costs

To account for variability of investment and net exports in the data I add capital adjustment costs into a benchmark model. Capital adjustment costs have been incorporated to slow the response of investment to a country-specific shock. Without the capital adjustment costs, capital owners have a strong incentive to locate new investment in the more productive country making investment and then net exports excessively volatile.

Here I compare the statistics of a benchmark model with those of the model where capital adjustment costs are incorporated. Table 3 presents simulation results of the model that incorporates consumption habits, leisure habits and capital adjustment costs. To explore the relevant effects of capital adjustment costs I shut down consumption habits ($b^c = 0$) and labor adjustment costs ($b^l = 0$). The fourth and third columns of Table 3 show that when compared to a benchmark model, introduction of capital adjustment costs substantially affects investment cross-correlation only. Still this correlation is far from the one we observe in the data (–0.32 in the model with capital adjustment costs vs. 0.29 in the data). Moreover, while impairing capital flows (0.93 vs. 1.38), capital adjustment costs make correlation of net export and GDP positive (0.15 vs. –0.26). With regard to domestic comovements, investment and net exports volatilities fall considerably (3.24 vs. 6.04 and 0.18 vs. 0.81 respectively) as consumption volatility rises (0.42 vs. 0.37).

The fact that capital adjustment costs bring volatility of investment and net exports in line with the data follows from our calibration procedure. Capital adjustment costs reduce volatility of investment since convexity of the adjustment cost function, $\phi(\cdot)$ implies that changing capital stock rapidly is more costly than changing it slowly. This is the reason why investment (net exports) volatility falls. Furthermore, volatility of consumption rises as a result of not having an investment change opportunity to shield consumption against a shock as in the benchmark model. This effect can be also seen from the impulse responses pictured in Figure 2 (impulse responses denoted by $b^c = 0$, $\varphi = 0$). The impulse response to a 1% increase in total factor productivity in the home country leads to much smaller investment response than in a no-capital adjustment cost case. Moreover, this presents a main force behind the reversal (and a fall) of capital flows – with small investment response (relative to response of consumption and output which are almost the same as in the no-capital adjustment cost case) the home country will experience capital outflow (net exports surplus) during the “good” times. Positive output response in the home country together with a net exports surplus generates a positive correlation of net exports and GDP. With regard to international correlations, capital adjustment costs make a sizeable change in investment cross-correlation only. This is because the costs imposed by adjustment on change of capital impair incentives to move investment to a more productive country – cross-correlation gets smaller. However this cost is still smaller that the return on investment in a more productive country – cross-correlation is still negative.

3.4.3 Adding Consumption Habits

Now I consider the economy in which agents form preferences over past consumption and where change of capital is subject to adjustment costs.[22] I compare the statistics of benchmark model with those of the model where consumption habits are characterized by habit importance parameter, $b^c = 0.8$.

The most important results of introducing consumption habits into a IRBC model with capital adjustment costs can be summarized as follows (comparing the results of the benchmark model in the third column of Table 3 and the results of the model with consumption habits and capital adjustment costs in the fifth column of Table 3, where I shut down leisure habits, $b^c = 0.8$, $b^l = 0$). The variability of both investments and net exports is reduced substantially – the standard deviation of the net exports falls from 0.81 to 0.20 and standard deviation of investment from 6.04 to 3.24. In addition, even though consumption habits alone generate more capital flows, in combination with capital adjustment costs the latter has much stronger effect on impairing capital flows (they fall from 1.38 to 0.84). In connection to this, the correlation of net exports and GDP gets positive (0.72 vs. –0.26). Finally, employment variability falls from 0.45 to 0.38. With regard to international statistics, capital adjustment costs and consumption habits have the largest effect on cross-correlation of investment and employment. While they generate large negative cross-correlation of employment (–0.78 vs. –0.37) both frictions help to resolve the investment puzzle – cross country investment correlation is now positive (0.31 vs. –0.78) and in the range as is observed in the data.

As far as the fall of investment and net exports volatility is concerned, the same logic applies as in the previous subsection. Furthermore, capital adjustment costs act as a tax on labor – labor volatility falls since the substitution effect coming from higher productivity (wage) becomes lower than in a benchmark case (but still dominates over the wealth effect) – agents are not willing to increase their labor supply as much as without the "tax". This is the reason why employment volatility falls. In connection to international comovements, the cross-correlation of investment is positive whereas that of employment is negative and much larger than in the benchmark model. International comovements can be explained in the following way. Consumption habits make investment volatility larger than in a model without consumption habits and with capital adjustment costs implying that a magnitude of adjustment costs, now, has to be larger to make investment volatility in line with the data. From Figure 2 we can see that the investment impulse response of foreign country is now small but more important, it is positive (denoted by $b^c = 0.8$, $\varphi = 0$), for our calibration procedure. This is because the

22 Incorporating consumption habits into the model without adjustment costs had its standard effect of increasing volatility of investment and net exports even further, and decreasing volatility of consumption. Consumption habits make the agents (locally) very risk-averse since now they want to smooth changes in consumption instead of consumption itself, which implies extreme consumption smoothing (in levels). This then gives rise to more volatile investment which serves as a buffer against productivity shock. With regard to international comovements, consumption habits do not make much difference with respect to the benchmark model. This result stems from the fact that habits do not change the "structure" of the economy in terms of changing the pattern of behavior of aggregates in both countries.

effect of capital adjustment costs prevails over the opportunity cost of not shifting the investment to a more productive country. In other words, the cost (stemming from transforming investment to capital) that agents have to "pay" if they invested abroad are bigger than the return on capital in the more productive country. This in turn, gives a rise to a positive cross-correlation of investment, fewer capital flows (in comparison to both benchmark model and model without habits and with adjustment costs) and positive correlation between net exports and GDP. Although capital adjustment costs and habits together help explain investment puzzle, they aggravate the employment puzzle – the negative cross-correlation of employment is much stronger that in the benchmark model. Because of the lower substitution effect, discussed above, capital adjustment costs bring the response of labor supply in the home country more in line with that in the foreign country (with the opposite sign) making cross-correlation stronger.[23]

3.4.4 Leisure Habits vs. Labor Adjustment Costs

Now I separately explore the effects of introducing two labor market frictions, demand-side friction – labor adjustment costs and supply-side friction – leisure habits, into the model with consumption habits and capital adjustment costs. I compare simulation results of the model with consumption habits, capital and labor adjustment costs (or leisure habits), where labor adjustment costs (or leisure habits) are characterized by $\varphi = 2$ (or $b^l = 0.7$) (the sixth column of Table 2 or the sixth column of Table 3, respectively) with the results of the model with consumption habits and capital adjustment costs (the fourth column of Table 2, where I shut down labor adjustment costs, $\varphi = 0$).

Introducing labor adjustment costs has the following main effects. In domestic terms, once labor adjustment costs are included in a model with consumption habits and capital adjustment costs, employment and output volatility and correlation of employment with GDP naturally go down. However, for our parametrization this change is small (0.36 vs. 0.38, 0.71 vs. 0.77 and 0.69 vs. 0.90 respectively). All these come as a result of the employment-smoothing effect – firms are reluctant to change the employment level as they are facing labor adjustment costs. With regard to international comovements, all cross correlations rise, which from the perspective of matching the data is favorable for the output cross-correlation only. As we have seen before, the main forces behind positive investment comovement include consumption habits and capital adjustment costs. Labor adjustment costs just accentuate the effect of two frictions by acting as a tax on investment. When a home country experiences a positive shock, the response of investment will be lower than in the case of no labor adjustment costs (see Figure 2) (but still positive) making investment correlation stronger. Even though the responses of employment are reduced substantially in "good times" once the labor adjustment costs are introduced (see Figure 2), the employment correlation becomes even

23 Notice that this did not happen in the model without habits and with adjustment costs since the substitution effect coming from "lower" adjustment costs i.e. the "lower tax" of that model did not induce agents in home country to decrease (relatively) their labor effort as much as in the model with both elements.

stronger. Positive correlation of investment and of TFP shock together with small responses of employment in both countries will induce positive correlation of output across the countries.

Now consider an economy in which instead of firms facing adjustment costs if they change the level of employment, agents have preference over past leisure as well as over past consumption. Because of leisure habits, agents will not be willing to change their labor supply decisions too much. The main effects of this kind of labor market friction in a model with consumption habits and capital adjustment costs on domestic and international comovements are different from those coming from labor adjustment costs (the last column of Table 3 shows the simulation results). In particular, employment volatility is lower than in the model without leisure habits (0.34 vs. 0.38). Furthermore, correlation of employment with GDP is higher and it is in line with the data (0.85 vs. 0.69), but lower than in the model without any labor market friction (0.85 vs. 0.90). Moreover, while labor adjustment costs increase the correlation of net exports and GDP, leisure habits will result in smaller correlation of net exports and GDP, although still too far from the negative correlation that we observe in the data. In an international environment, favorable effects of leisure habits include the increase in output cross-correlations (0.07 vs. 0.00) and a fall in consumption cross-correlation (0.69 vs. 0.80). On the other hand, employment and investment correlations move in the opposite direction from what is needed to account for the correlations that we observe in the data (–0.83 vs. –0.78 and 0.22 vs. 0.31 respectively). The explanations for output, investment and employment comovements with leisure habits is similar to that with labor adjustment costs. The only difference between the two labor market frictions, in terms of international comovements, pertains to consumption correlation. The decline of consumption correlation can be traced from the risk sharing equation. This equation requires that marginal utilities for both countries should be the same in any period.[24] Since in the labor adjustment costs case labor is a quasi-fixed factor of production, this equality is driven solely by consumption comovements. With leisure habits, an agent will be able to influence the equality of marginal utilities by changing not only the level of labor supply decision but also by changing the habit-adjusted labor supply. This magnifies the effect of nonseparability in the utility between consumption and leisure and therefore lowers consumption correlation across countries.

3.4.5 Sensitivity Analysis

The results discussed in the previous section are conditional on parameter values that I could not calibrate from the data. To address this issue, I repeat the analysis carried out in the previous section, using different values of habit importance parameters, $b^c = \{0, 0.4, 0.8\}$ and $b^l = \{0, 0.4, 0.8\}$, and different values of labor adjustment costs, $\varphi = \{0, 1, 20\}$. Table 4 reports simulation results for different

24 Notice that the expectation terms will cancel each other out since the expectation is taken with respect to the same joint distribution of the shock process vector.

values of b^c and φ corresponding to analysis the results of which are summarized in Table 2. Table 5 shows the results of sensitivity analysis of different values of b^c and b^l corresponding to simulation exercise the results of which are summarized in Table 3. Other parameter values in both sensitivity analyses are the same as in the baseline analyses.

Increasing the importance of consumption habits, b^c, given the labor adjustment cost parameter, has an important effect on investment and employment cross-correlations and on correlation between output and net exports (see Table 4). Only the first effect of positive investment cross-correlation positive coming from high importance of consumption habits is desirable as far the data is concerned. It seems that "intermediate" values of $b^c = 0.4$ do not have much quantitative relevance for any domestic or international statistics. The results indicate that only a high importance of consumption habits is sufficient for generating positive comovement in investment.

Increasing the value of labor adjustment costs, φ, given the consumption importance parameter, is not quantitatively important for any statistics. It seems that φ taking higher values than 20 would not help in resolving international puzzles since higher labor adjustment costs bring about even stronger cross-correlations of consumption, investment and employment, which is not in line with the data.

Making leisure habits more important in consumers' utility function (see Table 5), given the value for consumption habits, magnifies the effects of nonseparability in utility between consumption and leisure and therefore lower consumption cross-correlation. Together with rising output cross-correlation, higher b^l brings about forces that lower the gap a bit between output and consumption cross-correlations (but not nearly closing the gap that represents the consumption puzzle). However, effects of higher b^l on investment and employment cross-correlations do not work towards resolving factor comovements puzzles.

4 Conclusion

The main goal of this paper was to explore the importance of different types of frictions in the market for goods and factors, which today constitute a large part of closed-economy RBC theory, for the character of international business cycles. First, I show that the IRBC model with consumption habits and capital adjustment costs can resolve the investment cross-correlation puzzle – the combination of two frictions provides a channel through which the adjustment costs become larger than the opportunity costs of not investing in a more productive country. However, solving the investment puzzle comes at the expense of too low capital flows, positive correlation of net export and GDP and even more puzzling cross-correlation of employment. Second, frictions on the labor market do not help to explain factor comovements (employment and investment puzzles), neither introduced alone in the IRBC model nor in combination with other frictions. While both labor adjustment costs and leisure habits increase the output correlation, only the effects of the latter present forces toward resolving the consumption cross-correlation puzzle (although not actually resolving it). This mainly comes as a result of leisure habits reducing consumption correlation through amplified effects on nonseparability between consumption and leisure.

Overall, this paper shows that "real" frictions that help explain many closed-economy salient facts have less success in resolving international comovement puzzles. Given that only a complete markets environment was considered here, the conclusion of this paper supports the results of Kehoe and Perri (2002) or Yakhin (2007), which show the importance of financial and contractual frictions in explaining the international transmission of business cycles.

Appendix

In the first part of the Appendix I show one way to decentralize the social planner's problem presented in the main text. In the second part of the Appendix, I describe the algorithm that was constructed to solve the model numerically.

Competitive Equilibrium

There exists an alternative formulation of the social planner's economy that views households and firms as interacting in the perfectly competitive markets for goods, capital and labor. Below I present a decentralized market mechanism that corresponds to the planner's optimal allocation from the main text.

Endowments

Each household has an endowment of one unit of time that can be allocated to leisure or work. The world economy has an initial stocks (identical for the two countries $j = \{1,2\}$) of capital, k_{j0}, consumption habits, h^c_{j0}, labor-augmenting technology, z_{j0} and initial amount of state contingent assets, a_{j0}. In the case of analyzing leisure habits, a world economy also starts with an initial stock of leisure, h^l_{j0}, or with an initial stock of labor, l_{j0}, in the case of examining labor adjustment costs. Notice that in the case of labor adjustment costs, labor hired in period t becomes productive only in period $t+1$. This can be interpreted as "time to build labor stock" or necessity to train workers before they get productive. Anyway, the decision about labor supply in $t+1$ is made in period t, or in other words, the labor supply decision is made before realization of the shock process in $t+1$. After the state of technology is realized, the labor market clears (subject to predetermined labor supply) at a competitive wage.

Households

In each period, in both home and foreign country, $j = \{1,2\}$ a representative household supplies labor to the firm in exchange for the wage w_{jt} that represents its labor income. From the total income it decides how much to consume and how much to save. Since markets are complete, asset trading opportunities consist of a full set of one-period Arrow securities representing a claim for consumption in $t+1$ and whose payment is contingent on realization of z_{t+1}. Let $a_{jt}(z_t)$ denotes the one-period Arrow security that a household brings into period t. Furthermore, $q(z_{t+1})$ is a price of a state-contingent bond that (loosely speaking[25]) gives the price of one unit of period $t+1$ consumption, contingent on the realization of z_{t+1} at $t+1$. The decisions to consume, save and supply labor are made so as to maximize the expected discounted lifetime utility function which represents preferences over consumption, c_{jt}, labor, l^s_{jt} and consumption habit stock, h^c_{jt} (in case of examining demand-side labor market friction households also have preferences over leisure habit stock, h^l_{jt}):

25 See Lucas (1978) for rigorous treatment and notation of the price of the state contingent bond.

$$\max_{\{c_{jt},l^s_{jt},a_{jt+1}(z_{t+1})\}_{t=0}^{\infty}} \sum_{t=0}^{\infty} \beta^t \int_{Z^t} u\left(c_{jt}, h^c_{jt}, l^s_{jt}, h^l_{jt}\right) u^t\left(z_0, dz^t\right) \quad (28)$$

subject to

$$c_{jt} + \int_Z q\left(z_{t+1}\right) a_{jt+1}\left(z_{t+1}\right) dz_{t+1} = w_{jt} l^s_{jt} + a_{jt}\left(z_t\right) \quad (29)$$

$$h^c_{jt+1} = h^c_{jt} + \lambda^c (c_{jt} - h^c_{jt}) \quad (30)$$

(in case of leisure habits:)

$$h^l_{jt+1} = h^l_{jt} + \lambda^l (1 - l_{jt} - h^l_{jt}) \quad (31)$$

$$a_{j0}(z_0),\ h^c_{j0},\ h^l_{j0},\ z_{j0} \text{ given for } j = \{1,2\}$$

with discount factor $0 < \beta < 1$.

To rule out the Ponzi schemes, I impose state-by-state borrowing constraint

$$-a_{jt+1}(z_{t+1}) \leq A_{jt+1} \quad (32)$$

where A_{jt+1} is natural debt limit.

Firms

In each country there is a representative firm that operates the technology $f(k_{jt}, l_{jt}, z_{jt})$. In each period, the firm decides how much labor to hire, l^d_{jt} and how much to invest, i_{jt} taking into account capital adjustment costs. In the case of labor adjustment costs, instead of deciding on labor demand, the firm decides on new employment, m_{jt} so as to maximize expected, present values of discounted profits (current and future cash flow) to its owners (a representative household):

$$\max_{\{i_{jt},x_{jt}\}_{t=0}^{\infty}} \sum_{t=0}^{\infty} \nu_{jt,0} \int_{Z^t} \left[f\left(k_{jt}, l_{jt}, z_{jt}\right) - g\left(m_{jt}, l_{jt}\right) - w_{jt} l_{jt} - i_{jt} \right] \mu^t\left(z_0, dz^t\right) \quad (33)$$

subject to

$$k_{jt+1} = (1-\delta) k_{jt} + \phi\left(\frac{i_{jt}}{k_{jt}}\right) k_{jt} \quad (34)$$

$$l_{jt+1} = (1-\psi) l_{jt} + m_{jt} \quad (35)$$

$$k_{j0},\ l_{j0},\ z_{j0} \text{ given for } j = \{1,2\}$$

where $x_{jt} = \{l^d_{jt}, m_{jt}\}$, depending on the presence of particular labor market friction. Furthermore, $\nu_{jt,0}$ is the firm's stochastic discount factor representing a marginal rate of substitution of consumption between the time period t and period 0 of the firm's owners in country $j = \{1,2\}$ given by

$$v_{jt,0} = \frac{\beta\left(u_1\left(c_{jt},h^c_{jt},l_{jt},h^l_{jt}\right)+\beta\lambda\int_Z\left[\sum_{i=0}^{\infty}\beta^i(1-\lambda)^i u_2\left(c_{jt+i+1},h^c_{jt+i+1},l_{jt+i+1},h^l_{jt+i+1}\right)\right]Q(z_t,dz_{t+1})\right)}{\left(u_1\left(c_{j0},h^c_{j0},l_{j0},h^l_{j0}\right)+\beta\lambda\int_Z\left[\sum_{i=0}^{\infty}\beta^i(1-\lambda)^i u_2\left(c_{j0+i+1},h^c_{j0+i+1},l_{j0+i+1},h^l_{j0+i+1}\right)\right]Q(z_t,dz_{t+1})\right)} \tag{36}$$

and $\phi(\cdot)$ and $g(\cdot)$ are capital and labor adjustment cost functions given in (24) and (25) respectively.

Market Equilibrium

In this economy, a competitive equilibrium consists of, for $j=1,2$, a list of stochastic processes for allocations for the households, $\left\{c_{jt},l^s_{jt}\right\}_{t=0}^{\infty}$, and for the firm $\left\{x_{jt},i_{jt}\right\}_{t=0}^{\infty}$, assets $\left\{a_{it+1}(z_{t+1})\right\}_{t=0}^{\infty}$, and prices $\left\{q_t(z_{t+1}),w_{jt}\right\}_{t=0}^{\infty}$, such that

1. given prices, and initial assets, consumption habit stock, $\{a_{j0}, h^c_{j0}\}_{j=1,2}$ (in the case of leisure habits initial stocks read as $\{a_{j0}, h^c_{j0}, h^l_{j0}\}_{j=1,2}$), $\left\{c_{jt},l^s_{jt}\right\}_{t=0}^{\infty}$ solves the consumer problem for each $j=\{1,2\}$,

2. given prices and initial capital $\{k_{j0}\}_{j=1,2}$, (in the case of labor adjustment costs there is also an initial stock of labor $\{l_{j0}\}_{j=1,2}$), the allocation $\left\{x_{jt},i_{jt}\right\}_{t=0}^{\infty}$ solves the representative firm problem for each $j=\{1,2\}$ where $x_{jt}=\{l^d_{jt}, m_{jt}\}$ depending on the presence of particular labor market friction.

3. markets clear

$$a_{1t+1}(z_{t+1})+a_{2t+1}(z_{t+1}) = 0 \tag{37}$$

$$l^s_{jt} = l^d_{jt} \tag{38}$$

$$\sum_{j=1}^{2}c_{jt}+\sum_{j=1}^{2}i_{jt}=\sum_{j=1}^{2}\left[f\left(k_{jt},l_{jt},z_{jt}\right)-g\left(m_{jt},l_{jt}\right)\right] \tag{39}$$

The Algorithm

I rely on log-linear polynomials in a parametrization of conditional expectations so that each conditional expectation is approximated by the following functional form (for each country $j=\{1,2\}$) as a function of states:

$$\psi_j(\theta_j;k_{1t}(\theta),h^c_{1t}(\theta),y_{1t}(\theta),z_{1t},k_{2t}(\theta),y_{2t}(\theta),z_{2t}) = \exp(\theta_{j1}+\theta_{j2}k_{1t}(\theta)+\theta_{j3}h^c_{1t}(\theta)+$$
$$+\ \theta_{j4}y^c_{1t}(\theta)+\ \theta_{j5}z_{1t}+\ \theta_{j6}k_{2t}(\theta)+\ \theta_{j7}h^c_{2t}(\theta)+\ +\theta_{j8}y_{2t}(\theta)+\ \theta_{j9}z_{2t})$$

where $\theta=(\theta_1,\theta_2)$, $\theta_j\in\mathbb{R}^9$ and where $y_{jt}(\theta)=h^l_{jt}(\theta)$ in the case of analyzing leisure habits or $y_{jt}(\theta)=l_{jt}(\theta)$ in the case of examining labor adjustment costs. The subscript of functional form, ψ_j and of parameter vector, θ_j denotes the parametrization for specific country $j=\{1,2\}$. One advantage of using the log-linear polynomial is that it guarantees the simulated series will be non-negative.

If expectation were correctly parametrized i.e. if there existed a θ^*_j such that $\psi_j(\theta^*_j;k_{1t}(\theta^*),h^c_{1t}(\theta^*),y_{1t}(\theta^*),z_{1t},k_{2t}(\theta^*),h^c_{2t}(\theta^*),y_{2t}(\theta^*),z_{2t})$ is a very good approximation to the true conditional expectation, then the decision rules would coincide with the true optimal decision rules and simulations of decision variables would represent realization from the true stochastic process (for the proof see Marcet and Marshall (1994)). Increasing the degree of polynomial would insure that there existed θ_j^* such that $\psi_j(\theta_j^*; k_{1t}(\theta^*), h_{1t}^c(\theta^*), y_{1t}(\theta^*), z_{1t}, k_{2t}(\theta^*), h_{2t}^c(\theta^*), y_{2t}(\theta^*), z_{2t})$ is an arbitrary good approximation to the true conditional expectation.

To obtain a numerical solution of the model I parametrize three conditional expectation functions, for each country, which I denote by $E_t^i(\cdot)$ where superscript i denotes the optimality condition ($i=1$ corresponds to expectation in the Euler equation (12), $i=2$ to expectation in the labor supply equation (13) and $i=3$ to expectation in the risk sharing condition (14)). In other words, for my functional forms and calibration, after rearranging the terms and applying the law of iterated expectations I parametrize the expectation in the Euler equation (12), $E_t^1(\cdot)$, expectation in labor supply equation (13), $E_t^2(\cdot)$, and expectation in risk sharing condition (14), $E_t^3(\cdot)$. Each expectation function is denoted by superscript $i = \{1,2,3\}$ for both $j = \{1,2\}$. Also, parameters corresponding to a parametrization of a given expectation will be denoted by the same superscript.

First, I rewrite the Euler equation (12) in such a way that I can parametrize its expectation for the quadratic value of investment, i_{jt}^2 for both countries, $j = \{1,2\}$. Next, I substitute the conditional expectation $E_t^1(\cdot)$ in (12) by a first degree log-linear polynomial that depends on state variables and vector of parameters θ_j^1 to get

$$i_{jt}^2 = \beta\psi_j(\theta_j^1; k_{1t}(\theta), h_{1t}^c(\theta), y_{1t}(\theta), z_{1t}, k_{2t}(\theta), h_{2t}^c(\theta), y_{2t}(\theta), z_{2t}) \tag{40}$$

where $y_{1t}(\theta)$ represents either leisure habit stock or labor stock depending on the labor market friction I am analyzing (as explained before).

Next, for $j = \{1,2\}$ I also use first degree log-linear polynomial (with parameter vector θ_j^2) to parametrize a conditional expectation $E_t^2(\cdot)$ in the labor supply equation (13). I parametrize the resulting conditional expectation for x_{jt} which represents either l_{jt} in case of analyzing leisure habits (where labor adjustment cost parameter $\varphi = 0$) or m_{jt} in the case of examining labor adjustment costs (where leisure habit importance parameter $b^l = 0$), for both countries, $j = \{1,2\}$. I substitute the conditional expectation $E_t^2(\cdot)$ in (12) by a first degree log-linear polynomial that depends on state variables and vector of parameters θ_j^2 to get

$$x_{jt} = \beta\psi_j(\theta_j^2; k_{1t}(\theta), h_{1t}^c(\theta), y_{1t}(\theta), z_{1t}, k_{2t}(\theta), h_{2t}^c(\theta), y_{2t}(\theta), z_{2t}) \tag{41}$$

Finally, for $j = \{1,2\}$ I also use first degree log-linear polynomial (with parameter vector θ_j^3) to parametrize a conditional expectation $E_t^3(\cdot)$ in the risk sharing condition (14) to get:

$$E_t^3[u_2(c_{1t}, h_{1t}^c, l_{1t}, h_{1t}^l)] = \beta\psi_j(\theta_j^3; k_{1t}(\theta), h_{1t}^c(\theta), y_{1t}(\theta), z_{1t}, k_{2t}(\theta), h_{2t}^c(\theta), y_{2t}(\theta), z_{2t}) \tag{42}$$

Once I have a parametrized expectation forms, the algorithm for solving the model can be described as follows.

- *Step* 1. Fix the initial vector of parameters, $\theta = (\theta_1^1, \theta_2^1, \theta_1^2, \theta_2^2, \theta_1^3, \theta_2^3)$, the stopping criterion (tolerance level) and draw sequences of the *TFP* shocks $\{z_{1t}, z_{2t}\}_{t=0}^{T}$ that obey (16) with T sufficiently large.[26]
- *Step* 2. Given the parametrized expectations and given the parameter vector θ, at time period t, solve for the decision variables $\{c_{jt}(\theta), i_{jt}(\theta), x_{jt}(\theta), \mathrm{k}_{jt+1}(\theta), \mathrm{y}_{jt+1}(\theta)\}_{j=1}^{2}$ from the system of risk sharing condition (14) and budget constraint (4) together with the laws of motion for the capital, consumption, leisure (or labor) stock (5), (6), (8) (or (7)), respectively. To do this, given the parametrized expectations in (40), (41) and (42) for both $j=\{1,2\}$ (hence given $\{i_{jt}\}_{j=1}^{2}$ and $\{x_{jt}\}_{j=1}^{2}$) calculate the values for the capital stock next period, k_{jt+1}, which follows from the corresponding equations of motion (5) and the values for y_{jt+1} – the values for the habits leisure stock next period, l_{jt}, in the case of analyzing demand-side friction on the labor market from (8) or labor stock next period, l_{jt+1}, in the case of analyzing supply-side friction on the labor market from (7). Also, given the parametrized expectations $i=\{1,2,3\}$ for both $j=\{1,2\}$ in (40), (41) and (42) the values of remaining decision variables $\{c_{1t}(\theta), c_{2t}(\theta)\}$ are a solution of the non-linear system of the following two equations in two unknowns: risk sharing condition (14) and the budget constraint (4).
- *Step* 3. For particular parametrization depending on θ use the realizations for the shocks, $\{z_{1t}, z_{2t}\}_{t=0}^{T}$ to obtain recursively a sequence for the decision variables $\{c_{jt}(\theta), i_{jt}(\theta), x_{jt}(\theta), k_{jt+1}(\theta), y_{jt+1}(\theta)\}_{t=0}^{T}$ for $j=\{1,2\}$ by repeating Step 2.
- *Step* 4. Compute the updated parameter vector $S(\theta) = (S(\theta_1^1), S(\theta_2^1), S(\theta_1^2), S(\theta_2^2), S(\theta_1^3), S(\theta_2^3))$ by running six non-linear least square regressions using the simulated realization $\{c_{1t}(\theta), i_{1t}(\theta), x_{1t}(\theta), k_{1t+1}(\theta), c_{2t}(\theta), i_{2t}(\theta), x_{2t}(\theta), k_{2t+1}(\theta)\}_{t=0}^{T}$ as data. In other words, for every $j=\{1,2\}$ and $i=\{1,2,3\}$ find $S(\theta_i^j)$ such that

$$S\left(\theta_j^i\right) = \arg\min_{\theta_i^j \in \mathbb{R}^9} \frac{1}{T} \sum_{t=0}^{T} \left| Y_{jt}^i - \psi_j\left(\theta_j^i; k_{1t}(\theta), h_{1t}^c(\theta), y_{1t}(\theta), z_{1t}, k_{2t}(\theta), h_{2t}^c(\theta), y_{2t}(\theta), z_{2t}\right) \right|^2 \tag{43}$$

where Y_{jt}^i denotes the dependent variable for country j, as an expression inside the conditional expectation $E_t^i(\cdot)$, for $i=\{1,2,3\}$.

26 In order to ensure higher accuracy of solution and correct impulse response functions I should choose a very large sample size such that the estimated parameter θ does not depend on the realization of the shock process. I manage to experiment with a sample size up to T=100 000. Even though there was a lot of variation in the estimated parameter vector in the estimation using a sample of T=10 000 and that for the sample size of T=100 000 the model's results did not change much. In addition, because of the computational time problem (for the solution of the model with habits alone the algorithm that used T=100 000 needed more than 10 days to converge to the rational expectation equilibrium) I report the results obtained using the sample size T=10 000.

- *Step* 5. Find a fixed point of the map S by iterating on steps 3 and 4 such that $\theta^* = S(\theta^*)$ (equal up to the tolerance level set in step 1) which gives the solution for the decision variables $\{c_{jt}(\theta^*), i_{jt}(\theta^*), x_{jt}(\theta^*), k_{jt+1}(\theta^*), nx_{jt}(\theta^*)\}_{t=0}^{T}$ for $j = \{1,2\}$ where nx_{jt} denotes the net exports defined as net absorption in country j.

References

Alonso-Carrera, J., J. Caballé, and X. Raurich (2004): *Consumption Externalities, Habit Formation and Equilibrium Efficiency*, Scandinavian Journal of Economics, 106(2), 231-251.

Alonso-Carrera, J., J. Caballe, and X. Raurich (2005): *Growth, Habit Formation, and Catching-up with the Joneses*, European Economic Review, 49(6), 1665-1691.

Alvarez-Cuadrado, F., G. Monteiro, and S. J. Turnovsky (2004): *Habit Formation, Catching Up with the Joneses, and Economic Growth*, Journal of Economic Growth, 9(1), 47-80.

Andolfatto, D. (1996): *Business Cycles and Labor-Market Search*, American Economic Review, 86(1), 112-132.

Backus, D. K., P. J. Kehoe, and F. E. Kydland (1992): *International Real Business Cycles*, Journal of Political Economy, 100(4), 745-775.

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

Beaubrun-Diant, E. K., and F. Tripier (2005): *Asset Returns and Business Cycles in Model with Investment Adjustment Costs*, Economic Letters, 86, 141-146.

Boldrin, M., L. J. Christiano, and J. D. M. Fisher (2001): *Habit Persistence, Asset Returns, and the Business Cycle*, American Economic Review, 91(1), 149-166.

Bouakez, H., and T. Kano (2006): *Learning-by-Doing or Habit Formation?*, Review of Economic Dynamics, 9(3), 508-524.

Carroll, C. D., J. Overland, and D. N. Weil (2000): *Saving and Growth with Habit Formation*, American Economic Review, 90(3), 341-355.

Chang, Y., T. Doh, and F. Schorfheide (2006): *Non-stationary hours in a DSGE model*, Discussion paper, Federal Reserve Bank of Philadelphia.

Christiano, L. J., M. Eichenbaum, and C. L. Evans (2005): N*ominal Rigidities and the Dynamic Effects of a Shock to Monetary Policy*, Journal of Political Economy, 113(1), 1-45.

Cogley, T., and J. M. Nason (1995): *Output Dynamics in Real-Business-Cycle Models*, American Economic Review, 85(3), 492-511.

Constantinides, G. M. (1990): Habit Formation: *A Resolution of the Equity Premium Puzzle*, Journal of Political Economy, 98(3), 519-543.

Cooley, T. F. (ed.) (1995): *Frontiers of Business Cycle Research*, Princeton University Press, Princeton, NJ.

Cooper, R., J. Haltiwanger, and J. L. Willis (2003): *Dynamics of labor demand: evidence from plant-level observations and aggregate implications*, Discussion paper, Federal Reserve Bank of Kansas City.

Diaz, A., J. Pijoan-Mas, and J.-V. Rios-Rull (2003): *Precautionary savings and wealth distribution under habit formation preferences*, Journal of Monetary Economics, 50(6), 1257-1291.

Eichenbaum, M. S., L. P. Hansen, and K. J. Singleton (1988): *A Time Series Analysis of Representative Agent Models of Consumption and Leisure Choice under Uncertainty*, The Quarterly Journal of Economics, 103(1), 51-78.

Fuhrer, J. C. (2000): *Habit Formation in Consumption and Its Implications for Monetary-Policy Models,* American Economic Review, 90(3), 367-390.

Heathcote, J., and F. Perri (2002): *Financial Autarky and International Business Cycles*, Journal of Monetary Economics, 49(3), 601-627.

Hotz, V. J., F. E. Kydland, and G. L. Sedlacek (1988): *Intertemporal Preferences and Labor Supply*, Econometrica, 56(2), 335-360.

Janko, Z. (2008): *Nominal Wage Contract, Labor Adjustment Costs and the Business Cycle,* Review of Economic Dynamics, Vol. 11(2), pp. 434-448, April.

Jermann, U. J. (1998): *Asset Pricing in Production Economies*, Journal of Monetary Economics, 41(2), 257-275.

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

Kollmann, R. (1996): *Incomplete Asset Markets and the Cross-country Consumption Correlation Puzzle*, Journal of Economic Dynamics and Control, 20(5), 945-961.

Lucas, Robert E, J. (1978): *Asset Prices in an Exchange Economy*, Econometrica, 46(6), 1429-1445.

Marcet, A. (1989): *Solving Stochastic Dynamic Models by Parameterizing Expectations*, Working paper, Carnegie Mellon University, Graduate School of Industrial Administration.

Marcet, A., and D. A. Marshall (1994): *Solving Nonlinear Rational Expectations Models by Parameterized Expectations: Convergence to Stationary Solutions*, Discussion Paper / Institute for Empirical Macroeconomics 91, Federal Reserve Bank of Minneapolis.

Mendoza, E. G. (1991): *Real Business Cycles in a Small Open Economy*, American Economic Review, 81(4), 797-818.

Merz, M. (1995): *Search in the labor market and the real business cycle*, Journal of Monetary Economics, 36(2), 269-300.

Shapiro, M. D. (1986): *The Dynamic Demand for Capital and Labor*, The Quarterly Journal of Economics, 101(3), 513-542.

Stokey, N., R. Lucas, and E. Prescott (1989): *Recursive Methods in Economic Dynamics*, Harvard University Press, Cambridge, MA.

Wen, Y. (1998): *Can a real business cycle model pass the Watson test?*, Journal of Monetary Economics, 42(1), 185-203.

Yakhin, Y. (2007): Staggered *wages, financial frictions, and the international comovement problem*, Review of Economic Dynamics, 10, 148-171.

Yun, T. (1996): *Nominal price rigidity, money supply endogeneity, and business cycles*, Journal of Monetary Economics, 37(2), 345-370.

Table 1 Parameter Values for the Benchmark Model and the Model with Frictions

Parameter		Calibrated values: Benchmark model	Calibrated values: Model with frictions	Targets
Technology				
Capital share	α	**0.36**	**0.36**	Labor/output=2/3
Depreciation rate	δ	**0.1**	**0.1**	Investment/output=0.25
Quit rate	ψ	**0.15**	**0.15**	Taken from the literature
Elasticity of investment (capital adj. cost parameter)	ξ	∞	–	Same inv. volatility of the model and data
Matrix of coefficients in VAR(1) of the shock process	R	$\begin{bmatrix} 0.95 & 0 \\ 0 & 0.95 \end{bmatrix}$		Taken from the literature
Covariance matrix of the shock process	Ω	$0.007^2 \begin{bmatrix} 1 & 0.25 \\ 0.25 & 1 \end{bmatrix}$		Taken from the literature
Labor adjustment cost parameter	φ	**0**	{**1,2,20**}	Taken from the literature and varies
Preference				
Discount rate	β	**0.984**	**0.984**	Net average interest rate=6.5%
Habit importance in consumption	b^c	**0**	{**0.4,0.8**}	Taken from the literature and varies
Habit importance in leisure	b^l	**0**	{**0.4,0.7,0.8**}	Taken from the literature and varies
Share of consumption in composite good	γ	**0.369**	–	Depends on b^l and b^c ; Investment/output=0.25, labor supply=1/3
Utility curvature	σ	**3.7**	–	Depends on γ; Intertemporal elasticity of consumption=1/2

Table 2 Business Cycle Statistics
Perfect Risk Sharing Model (Benchmark Model) and the Model with Consumption Habits, Capital and Labor Adjustment Costs

Statistic	Data	Models with different frictions			
		Perfect risk sharing (b^c=0, φ=0, $\xi=\infty$)	Capital adjustment costs (b^c=0, φ=0, $\xi<\infty$)	Cons. habits, cap. adj. cost (b^c=0.8, φ=0, $\xi<\infty$)	Cons. habits, cap. & labor adj. cost (b^c=0.8, φ=2, $\xi<\infty$)
Volatility (% st. dev.)					
GDP	1.72 (0.20)	0.90	0.83	0.77	0.71
Net exports/GDP	0.15 (0.01)	0.81	0.18	0.20	0.17
% st. dev. relative to GDP					
Consumption	0.79 (0.05)	0.37	0.42	0.28	0.30
Investment	3.24 (0.17)	6.04	3.24	3.24	3.24
Employment	0.63 (0.04)	0.45	0.43	0.38	0.36
Domestic comovement					
Correlation with GDP					
Consumption	0.87 (0.03)	0.92	0.93	0.64	0.62
Investment	0.93 (0.02)	0.73	0.94	0.95	0.96
Employment	0.86 (0.03)	0.98	0.97	0.90	0.69
Net exports/GDP	–0.36 (0.09)	–0.26	0.15	0.72	0.72
International correlations					
GDP	0.51 (0.13)	–0.02	0.07	0.00	0.06
Consumption	0.32 (0.17)	0.65	0.75	0.80	0.82
Investment	0.29 (0.17)	–0.78	–0.32	0.31	0.32
Employment	0.43 (0.11)	–0.37	–0.42	–0.78	–0.84
Capital flows (in %)					
Net exports/GDP	1.10	1.38	0.93	0.84	0.83

Note: Parameters b^c, ξ and φ denote the consumption habit importance parameter in the utility function and the parameter of capital and labor adjustment costs, respectively. Data column contains estimates (standard errors in parenthesis) of the business cycle moments taken from Kehoe and Perri (2002), except for the Capital flow statistic which was calculated from the NIPA. The Volatility, Standard deviations and Domestic comovement of the Data column pertain to the U.S. quarterly time series sample 1970:1-1998:4. International comovements statistics are calculated from U.S. data and aggregated data of 15 European countries – all the statistics are based on logged (except for the net exports) and HP filtered data with the smoothing parameter of 1600. The model statistics are computed from a single simulation on a 10 000 periods time series of logged and HP-filtered data (with smoothing parameter 1600).

Table 3 Business Cycle Statistics
Perfect Risk Sharing Model (Benchmark Model) and the Model with Consumption and Leisure Habits and Capital Adjustment Costs

Statistic	Data	Models with different frictions			
		Perfect risk sharing (b^c=0, b^l=0, $\xi=\infty$)	Capital adjustment costs (b^c=0, b^l=0, $\xi<\infty$)	Cons. habits, cap. adj. cost (b^c=0.8, b^l=0, $\xi<\infty$)	Cons. habits, cap. & labor adj. cost (b^c=0.8, b^l=0.7, $\xi<\infty$)
Volatility (% st. dev.)					
GDP	1.72 (0.20)	0.90	0.83	0.77	0.75
Net exports/GDP	0.15 (0.01)	0.81	0.18	0.20	0.15
% st. dev. relative to GDP					
Consumption	0.79 (0.05)	0.37	0.42	0.28	0.28
Investment	3.24 (0.17)	6.04	3.24	3.24	3.23
Employment	0.63 (0.04)	0.45	0.43	0.38	0.34
Domestic comovement					
Correlation with GDP					
Consumption	0.87 (0.03)	0.92	0.93	0.64	0.80
Investment	0.93 (0.02)	0.73	0.94	0.95	0.97
Employment	0.86 (0.03)	0.98	0.97	0.90	0.85
Net exports/GDP	–0.36 (0.09)	–0.26	0.15	0.72	0.70
International correlations					
GDP	0.51 (0.13)	–0.02	0.07	0.00	0.07
Consumption	0.32 (0.17)	0.65	0.75	0.80	0.69
Investment	0.29 (0.17)	–0.78	–0.32	0.31	0.22
Employment	0.43 (0.11)	–0.37	–0.42	–0.78	–0.83
Capital flows (in %)					
Net exports/GDP	1.10	1.38	0.93	0.84	0.82

Note: Parameters b^c, b^l and ξ denote the consumption and leisure habit importance parameter in the utility function and the parameter of capital adjustment costs, respectively. Data column contains estimates (standard errors in parenthesis) of the business cycle moments taken from Kehoe and Perri (2002), except for the Capital flow statistic which was calculated from the NIPA. The Volatility, Standard deviations and Domestic comovement of the Data column pertain to the U.S. quarterly time series sample 1970:1-1998:4. International comovements statistics are calculated from U.S. data and aggregated data of 15 European countries – all the statistics are based on logged (except for the net exports) and HP-filtered data with the smoothing parameter of 1600. The model statistics are computed from a single simulation on a 10 000 periods time series of logged and HP-filtered data (with smoothing parameter 1600).

Table 4 Business Cycle Statistics – Sensitivity Analysis
Economy with Consumption Habits, Capital and Labor Adjustment Costs

Statistic	Data	Sensitivity analysis with respect to b^c and φ								
		$b^c=0$			$b^c=0.4$			$b^c=0.8$		
		$\varphi=0$	$\varphi=1$	$\varphi=20$	$\varphi=0$	$\varphi=1$	$\varphi=20$	$\varphi=0$	$\varphi=1$	$\varphi=20$
Volatility (% st. dev.)										
GDP	1.72 (0.20)	0.83	0.77	0.69	0.82	0.76	0.69	0.77	0.71	0.66
Net exports/GDP	0.15 (0.01)	0.18	0.19	0.16	0.12	0.14	0.11	0.20	0.17	0.17
% st. dev. relative to GDP										
Consumption	0.79 (0.05)	0.42	0.42	0.41	0.39	0.40	0.40	0.28	0.30	0.31
Investment	3.24 (0.17)	3.24	3.23	3.25	3.23	3.24	3.25	3.24	3.24	3.25
Employment	0.63 (0.04)	0.43	0.42	0.32	0.43	0.42	0.31	0.38	0.37	0.27
Domestic comovement										
Correlation with GDP										
Consumption	0.87 (0.03)	0.93	0.9	0.87	0.88	0.86	0.81	0.64	0.62	0.59
Investment	0.93 (0.02)	0.94	0.91	0.91	0.94	0.94	0.95	0.95	0.96	0.95
Employment	0.86 (0.03)	0.97	0.83	0.68	0.97	0.82	0.66	0.90	0.70	0.57
Net exports/GDP	–0.36 (0.09)	0.15	0.26	0.30	0.35	0.37	0.45	0.72	0.72	0.74
International correlations										
GDP	0.51 (0.13)	0.07	0.09	0.15	0.07	0.11	0.17	0.00	0.04	0.17
Consumption	0.32 (0.17)	0.75	0.75	0.84	0.78	0.78	0.85	0.80	0.81	0.88
Investment	0.29 (0.17)	–0.32	–0.28	–0.24	–0.14	–0.12	–0.07	0.31	0.32	0.47
Employment	0.43 (0.11)	–0.42	–0.48	–0.55	–0.47	–0.46	–0.60	–0.78	–0.84	–0.85
Capital flows (in %)										
Net exports/GDP	1.1	0.93	0.91	0.87	0.91	0.89	0.87	0.84	0.83	0.80

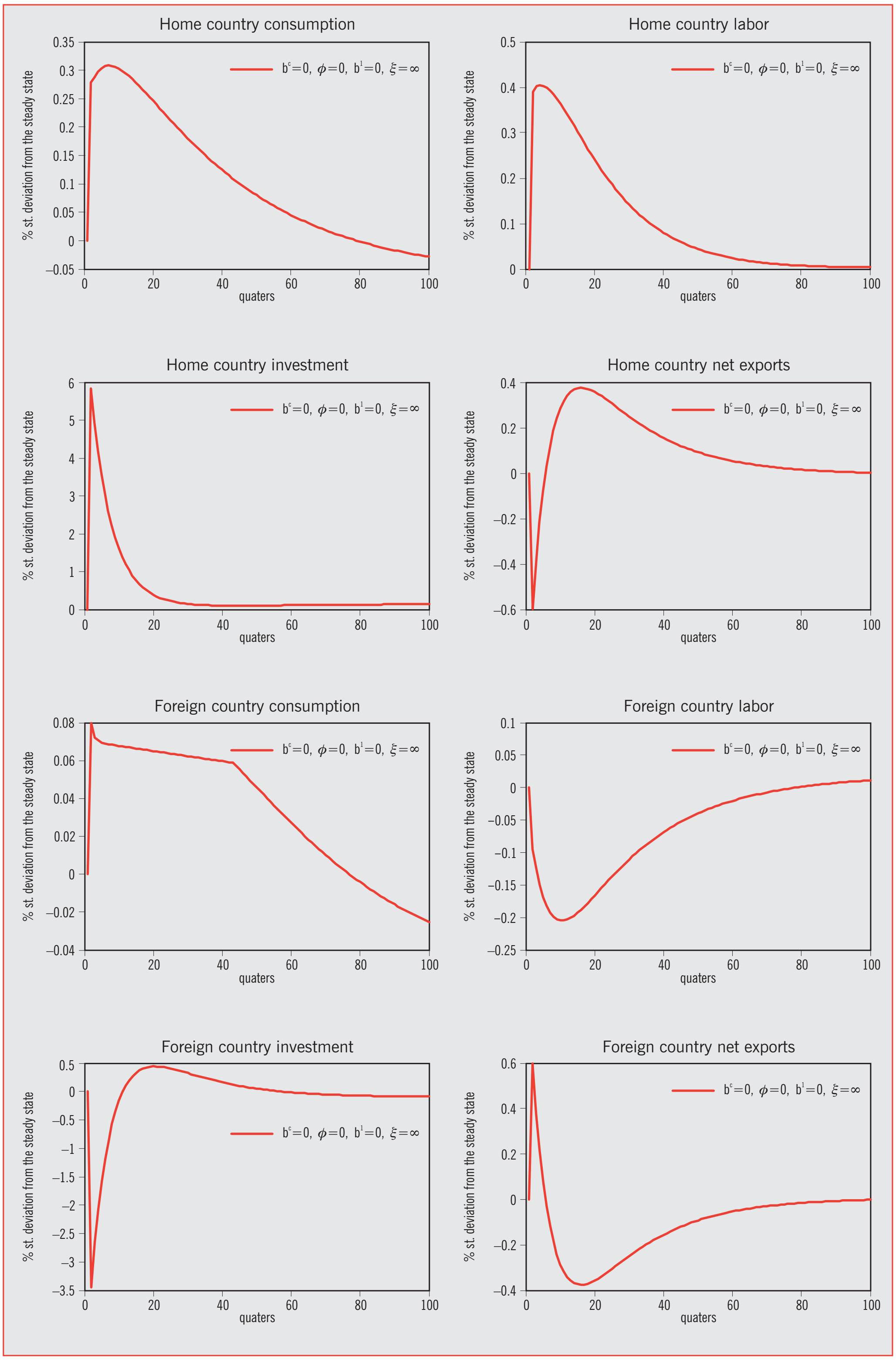
Note: Parameters b^c and φ denote the consumption habit importance parameter in the utility function and parameter of labor adjustment costs, respectively. Data column contains estimates (standard errors in parenthesis) of the business cycle moments taken from Kehoe and Perri (2002), except for the Capital flow statistic which was calculated from the NIPA. The Volatility, Standard deviations and Domestic comovement of the Data column pertain to the U.S. quarterly time series sample 1970:1-1998:4. International comovements statistics are calculated from U.S. data and aggregated data of 15 European countries – all the statistics are based on logged (except for the net exports) and HP-filtered data with the smoothing parameter of 1600. The model statistics are computed from a single simulation on a 10 000 periods time series of logged and HP-filtered data (with smoothing parameter 1600).

Table 5 Business Cycle Statistics – Sensitivity Analysis
Economy with Consumption and Leisure Habits and Capital Adjustment Costs

Statistic	Data	Sensitivity analysis with respect to b^c and b^l								
		b^c=0			b^c=0.4			b^c=0.8		
		b^l=0	b^l=0.4	b^l=0.8	b^l=0	b^l=0.4	b^l=0.8	b^l=0	b^l=0.4	b^l=0.8
Volatility (% st. dev.)										
GDP	1.72 (0.20)	0.83	0.81	0.72	0.82	0.81	0.72	0.77	0.77	0.74
Net exports/GDP	0.15 (0.01)	0.18	0.20	0.23	0.12	0.12	0.16	0.20	0.17	0.14
% st. dev. relative to GDP										
Consumption	0.79 (0.05)	0.42	0.43	0.47	0.39	0.39	0.44	0.28	0.28	0.29
Investment	3.24 (0.17)	3.24	3.25	3.23	3.23	3.23	3.24	3.24	3.24	3.24
Employment	0.63 (0.04)	0.43	0.40	0.30	0.41	0.40	0.31	0.38	0.37	0.32
Domestic comovement										
Correlation with GDP										
Consumption	0.87 (0.03)	0.93	0.93	0.94	0.88	0.92	0.94	0.64	0.7	0.83
Investment	0.93 (0.02)	0.94	0.93	0.91	0.96	0.96	0.95	0.95	0.97	0.97
Employment	0.86 (0.03)	0.97	0.96	0.83	0.96	0.96	0.84	0.90	0.86	0.84
Net exports/GDP	–0.36 (0.09)	0.15	0.09	0.03	0.35	0.23	0.03	0.72	0.72	0.67
International correlations										
GDP	0.51 (0.13)	0.07	0.07	0.10	0.07	0.09	0.11	0.00	0.03	0.10
Consumption	0.32 (0.17)	0.75	0.71	0.61	0.78	0.74	0.63	0.80	0.78	0.65
Investment	0.29 (0.17)	–0.32	–0.34	–0.36	–0.14	–0.15	–0.23	0.31	0.22	0.20
Employment	0.43 (0.11)	–0.42	–0.48	–0.62	–0.47	–0.44	–0.63	–0.78	–0.83	–0.84
Capital flows (in %)										
Net exports/GDP	1.10	0.93	0.93	0.93	0.91	0.91	0.91	0.84	0.83	0.80

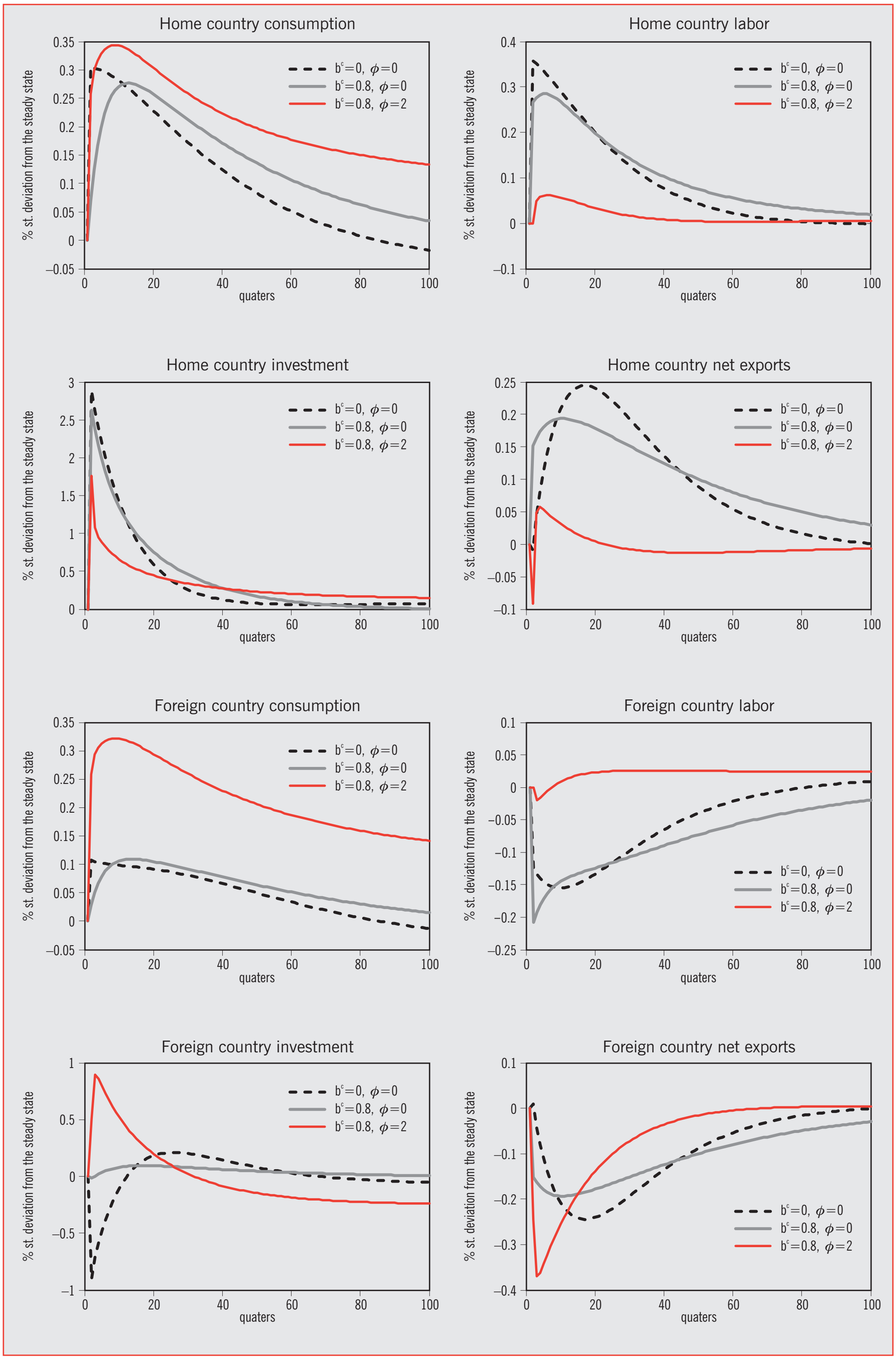
Note: Parameters b^c and b^l denote the consumption and leisure habit importance parameter in the utility function, respectively. Data column contains estimates (standard errors in parenthesis) of the business cycle moments taken from Kehoe and Perri (2002), except for the Capital flow statistic which was calculated from the NIPA. The Volatility, Standard deviations and Domestic comovement of the Data column pertain to the U.S. quarterly time series sample 1970:1-1998:4. International comovements statistics are calculated from U.S. data and aggregated data of 15 European countries – all the statistics are based on logged (except for the net exports) and HP-filtered data with the smoothing parameter of 1600. The model statistics are computed from a single simulation on a 10 000 periods time series of logged and HP-filtered data (with smoothing parameter 1600).

Figure 1 Impulse Response Functions of Home and Foreign Country Variables Implied by the Model without Any Frictions



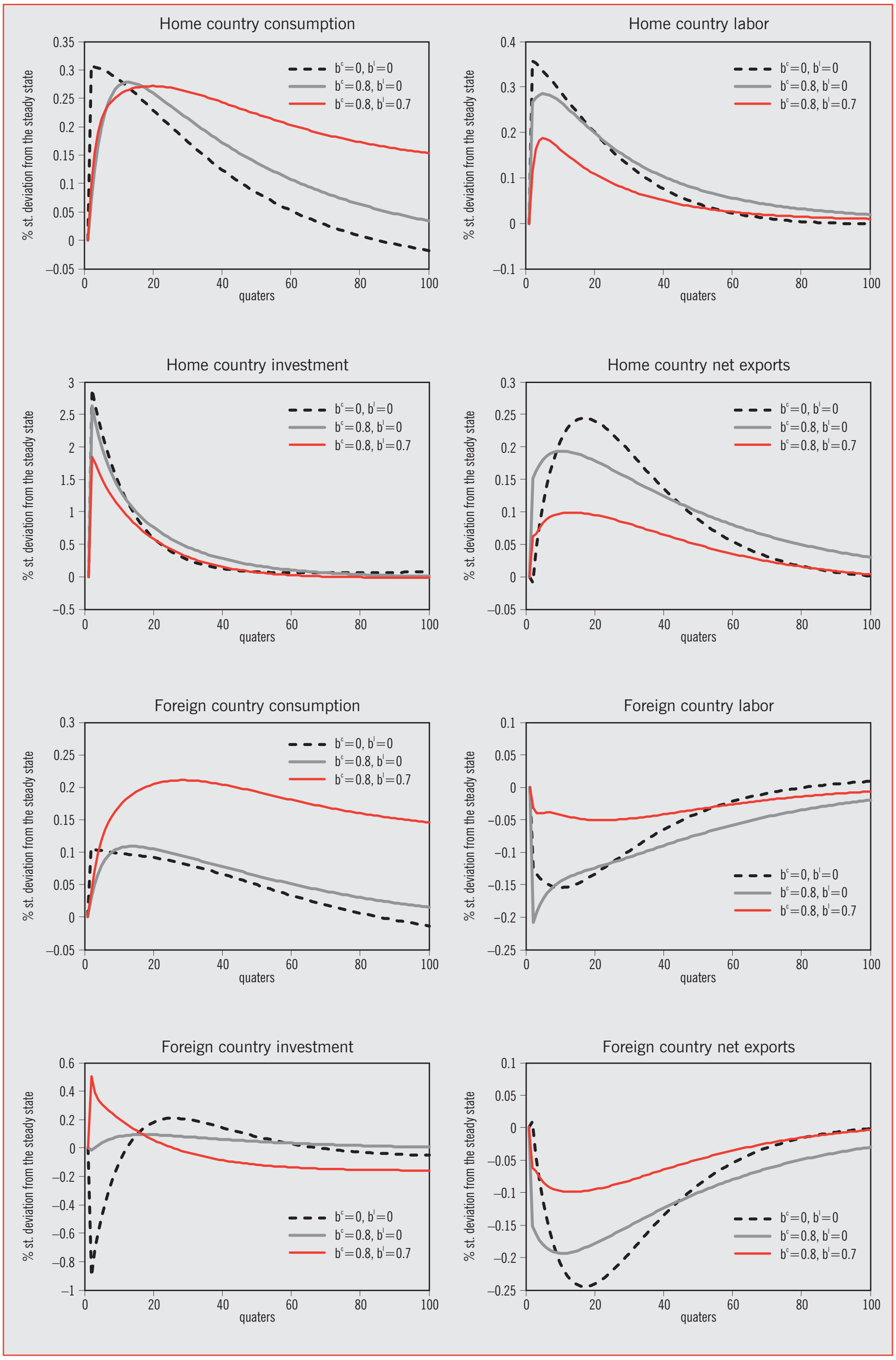
Note: b^c, b^l, ξ, φ denote consumption habits importance parameter, leisure habits importance parameter, capital adjustment cost parameter and labor adjustment cost parameter, respectively.

Figure 2 Impulse Response Functions of Home and Foreign Country Variables Implied by the Model with Capital Adjustment Costs, Model with Consumption Habits and Capital Adjustment Costs and Model with Consumption Habits, Capital and Labor Adjustment Costs



Note: $b^c=0$, $\varphi=0$ represents the impulse response of the corresponding variable of the model with capital adjustment costs (without consumption habits and no labor adjustment costs),
$b^c=0.8$, $\varphi=0$ represents the impulse response of the corresponding variable of the model with capital adjustment costs and consumption habits (and no labor adjustment costs), and
$b^c=0$, $\varphi=2$ represents the impulse response of the corresponding variable of the model with capital adjustment costs, consumption habits and labor adjustment costs.

Figure 3 Impulse Response Functions of Home and Foreign Country Variables Implied by the Model with Capital Adjustment Costs, Model with Consumption Habits and Capital Adjustment Costs and Model with Consumption and Leisure Habits, Capital Adjustment Costs



Note: $b^c=0$, $b^l=0$ represents the impulse response of the corresponding variable of the model with capital adjustment costs (without consumption and leisure habits),
$b^c=0.8$, $b^l=0$ represents the impulse response of the corresponding variable of the model with capital adjustment costs and consumption habits (without leisure habits), and
$b^c=0.8$, $b^l=0.7$ represents the impulse response of the corresponding variable of the model with capital adjustment costs, consumption and leisure habits.

The following Working Papers have been published:

No.	Date	Title	Author(s)
W–1	December 1999	Croatia in the Second Stage of Transition, 1994–1999	Velimir Šonje and Boris Vujčić
W–2	January 2000	Is Unofficial Economy a Source of Corruption?	Michael Faulend and Vedran Šošić
W–3	September 2000	Measuring the Similarities of Economic Developments in Central Europe: A Correlation between the Business Cycles of Germany, Hungary, the Czech Republic and Croatia	Velimir Šonje and Igeta Vrbanc
W–4	September 2000	Exchange Rate and Output in the Aftermath of the Great Depression and During the Transition Period in Central Europe	Velimir Šonje
W–5	September 2000	The Monthly Transaction Money Demand in Croatia	Ante Babić
W–6	August 2001	General Equilibrium Analysis of Croatia's Accession to the World Trade Organization	Jasminka Šohinger, Davor Galinec and Glenn W. Harrison
W–7	February 2002	Efficiency of Banks in Croatia: A DEA Approach	Igor Jemrić and Boris Vujčić
W–8	July 2002	A Comparison of Two Econometric Models (OLS and SUR) for Forecasting Croatian Tourism Arrivals	Tihomir Stučka
W–9	November 2002	Privatization, Foreign Bank Entry and Bank Efficiency in Croatia: A Fourier-Flexible Function Stochastic Cost Frontier Analysis	Evan Kraft, Richard Hofler and James Payne
W–10	December 2002	Foreign Banks in Croatia: Another Look	Evan Kraft
W–11	October 2003	The Impact of Exchange Rate Changes on the Trade Balance in Croatia	Tihomir Stučka
W–12	August 2004	Currency Crisis: Theory and Practice with Application to Croatia	Ivo Krznar
W–13	June 2005	Price Level Convergence: Croatia, Transition Countries and the EU	Danijel Nestić
W–14	March 2006	How Competitive Is Croatia's Banking System?	Evan Kraft
W–15	November 2006	Microstructure of Foreign Exchange Market in Croatia	Tomislav Galac, Ante Burić, Ivan Huljak
W–16	December 2006	Short-Term Forecasting of Inflation in Croatia with Seasonal ARIMA Processes	Andreja Pufnik and Davor Kunovac
W–17	February 2008	Modelling of Currency outside Banks in Croatia	Maroje Lang, Davor Kunovac, Silvio Basač, Željka Štaudinger

Guidelines to Authors

In its periodical publications *Working Papers, Surveys and Discussion Papers,* the Croatian National Bank publishes scientific and scholarly papers of the Bank's employees, visiting scholars, and other associate contributors.

After the submission, the manuscripts shall be subject to peer review and classification by the Manuscript Review and Classification Committee. The authors shall be informed of the acceptance or rejection of their manuscript for publication within two months following the manuscript submission.

Manuscripts are submitted and published in Croatian and/or English language.

Manuscripts submitted for publication should meet the following requirements:

Manuscripts should be submitted via e-mail, in magnetic or optical storage media, accompanied by one printed paper copy. The acceptable text format is Word.

The first page of the manuscript should contain the article title, first and last name of the author and his/her academic degree, name of the institution with which the author is associated, author's co-workers, and the complete mailing address of the corresponding author to whom a copy of the manuscript with requests for corrections shall be sent.

Additional information, such as acknowledgments, may be included in the first page. If this information is extensive, it is preferred to incorporate it within the text, whether at the end of the introductory section or in the special section preceding the list of references.

The second page should contain the abstract and the key words. The abstract is required to be explicit, descriptive, written in third person, consisting of not more than 250 words (maximum 1500 characters). The abstract should be followed by maximum 5 key words.

A single line spacing and A4 paper size should be used. The text must not be formatted, apart from applying bold and italic script to certain parts of the text. Titles must be numerated and separated from the text by a double line spacing, without formatting.

Tables, figures and charts that are a constituent part of the paper must be well laid out, containing: number, title, units of measurement, legend, data source, and footnotes. The footnotes referring to tables, figures and charts should be indicated by lower-case letters (a,b,c…) placed right below. When the tables, figures and charts are subsequently submitted, it is necessary to mark the places in the text where they should be inserted. They should be numbered in the same sequence as in the text and should be referred to in accordance with that numeration. If the tables and charts were previously inserted in the text from other programs (Excel…), these databases in the Excel format should also be submitted (charts must contain the corresponding data series).

The preferred formats for illustrations are EPS or TIFF with explanations in 8 point Helvetica (Ariel, Swiss). The scanned illustration must have 300 dpi resolution for gray scale and full color illustration, and 600 dpi for lineart (line drawings, diagrams, charts).

Formulae must be legible. Indices and superscript must be explicable. The symbols' meaning must be given following the equation where they are used for the first time. The equations in the text referred to by the author should be marked by a serial number in brackets closer to the right margin.

Notes at the foot of the page (footnotes) should by indicated by Arabic numerals in superscript. They should be brief and written in a smaller font than the rest of the text.

References cited in the text are listed at the last page of the manuscript in the alphabetical order, according to the authors' last names. References should also include data on the publisher, city and year of publishing.

Publishing Department maintains the right to send back for the author's revision the accepted manuscript and illustrations that do not meet the above stated requirements.

Printed paper copies and diskettes containing manuscript files shall not be returned.

All contributors who wish to publish their papers are welcomed to do so by addressing them to the Publishing Department, following the above stated guidelines.

The Croatian National Bank publications:

Croatian National Bank – *Annual Report*
Regular annual publication surveying annual monetary and general economic developments as well as statistical data.

Croatian National Bank – *Semi-annual Report*
Regular semi-annual publication surveying semi-annual monetary and general economic developments and statistical data.

Croatian National Bank – *Quarterly Report*
Regular quarterly publication surveying quarterly monetary and general economic developments.

Banks Bulletin
Publication providing survey of data on banks.

Croatian National Bank – *Bulletin*
Regular monthly publication surveying monthly monetary and general economic developments and monetary statistics.

Croatian National Bank – *Working Papers*
Occasional publication containing shorter scientific papers written by the CNB employees, visiting scholars and associate contributors.

Croatian National Bank – *Surveys*
Occasional publication containing papers of informative and surveying character written by the CNB employees, visiting scholars and associate contributors.

Croatian National Bank – *Discussion Papers*
Occasional publication containing discussion papers written by CNB employees, visiting scholars and associate contributors.

The Croatian National Bank also issues other publications such as, for example proceedings of conferences organized or co-organized by the CNB, books and papers or books and papers translations of special interest to the CNB as well as other similar publications.

ISSN 1331–8586