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Consumer Preferences and the Reliability of Euler Equation Tests of Capital Mobility – Some Simulation-Based Evidence

by

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Abstract

The globalization of international financial markets has renewed interest in the measurement of capital mobility. Consumption-based tests such as the Euler equation test are commonly used. These tests, however, are derived under restrictive assumptions on consumer behavior. In this paper, we ask how the Euler equation test of capital mobility performs if these restrictive assumptions are relaxed. We simulate a dynamic general equilibrium two-country model under alternative assumptions regarding consumer preferences and use the simulated time series to test for the degree of capital mobility. We find that the Euler equation test discriminates fairly well between high and low capital mobility regimes even if the restrictive assumptions on consumer behavior used to derive the test are not satisfied.

Keywords: international capital mobility; Euler equation tests; consumption smoothing; new open economy macro models

JEL classification: F36; F41; F47; E32; G15

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1 Motivation

The globalization of financial markets is typically considered one of the key manifestations of the increasing worldwide economic integration. This process has been fostered by the abolition of legal restrictions on cross-border capital movements and by technological advances that have lowered information and communication costs. As a consequence, global capital flows have increased substantially, and interest in the measurement of capital mobility has been renewed.

In the empirical literature, several tests of capital mobility have been advanced. Generally, quantity measures such as the test on savings-investment correlations proposed by Feldstein and Horioka (1980) are distinguished from price or arbitrage measures such as interest-parity tests. (For surveys of the empirical literature see, e.g., Bayoumi (1999), Lemmen (1998), Montiel (1994), or Obstfeld (1986).) However, tests based on savings-investment correlations can be criticized both on empirical and theoretical grounds (see, e.g., Finn 1990, Cardia 1992, Baxter and Crucini 1993, Mendoza 1994). Moreover, interest parity tests can, in a strict sense, be applied only to relatively narrow financial market segments (Obstfeld 1995). Therefore, Obstfeld (1989, 1994) has proposed alternative quantity measures which are based on the consumption Euler equation and on the (cross-country) correlation of output and consumption.

Obstfeld's (1989) test of capital mobility is based on the assumption that the Euler equation characterizes the optimal intertemporal consumption choice of optimizing households. In a world of perfect capital mobility, consumers should be able to smoothen consumption over time by borrowing and lending abroad. Assuming that domestic and foreign households have identical iso-elastic utility functions, the marginal rates of consumption should be identical across countries if financial markets are perfectly integrated, i.e., if households at home and abroad have access to the same risk-free bonds. Also, domestic and foreign consumption should be closely correlated.

Empirical applications of Euler equation tests include Lemmen and Eijffinger (1995), who find that, for the European Union, the degree of capital mobility is not complete and that it differs significantly among countries. Montiel (1994) finds mixed evidence on financial integration for developing countries. Obstfeld (1989) finds differences in the marginal rates of substitution across countries. These somewhat mixed empirical results raise the issue of how reliable the Euler equation test is for measuring capital mobility.

One problem with the interpretation of Euler equation tests is that a rejection of the underlying null hypothesis can have two interpretations. One the one hand, a rejection of the null hypothesis of the test could indicate that international capital mobility is actually low. On the other hand, a rejection of the null could indicate that one or more of the assumptions underlying the derivation of the test are not satisfied. In particular, the test involves a joint test of capital market integration and the assumption that the intertemporal substitution elasticities do not differ across countries (Bayoumi and MacDonald 1995). This latter assumption, of course, may be overly restrictive.

In this paper, we study the influence of specific assumptions on consumer preferences for the reliability of Euler equation tests in a general equilibrium setting. To this end, we follow Baxter and Crucini (1993) and Mendoza (1994) and use a simulation-based experiment. We proceed in two steps. In a first step, we set up a dynamic stochastic two-country general equilibrium model with sticky prices. The model is a variant of the model developed by Obstfeld and Rogoff (1995), which centers around the consumption-smoothing properties of the current account of the balance of payments and is therefore a natural candidate for studying intertemporal consumption choices. In order to discriminate between regimes of high and low capital mobility, we follow Sutherland (1996) in allowing for the possibility that internationally traded financial assets are imperfect substitutes. We check the empirical fit of our model by comparing the summary statistics for the simulated time series from our model to those observed in data for the G7 countries.

In a second step, we use the time series that drop out of our simulations to perform Euler equation tests of capital mobility as proposed by Obstfeld (1989). Our results suggest that, even if consumer preferences are not of the most basic isoelastic type and if they differ across countries, Euler equation tests are relatively informative with regard to the degree of capital mobility. In fact, in all cases we consider, the simulated sampling distribution of the Euler equation estimator under low international capital mobility is significantly different from its sampling distribution under high capital mobility.

Our study contributes to the literature using simulation-based experiments to assess the properties of measures of capital mobility. Simulating real business cycle models, Finn (1990), Cardia (1992), and Baxter and Crucini (1993) find that saving-investment-based tests of international capital mobility may be rather uninformative. Mendoza (1994) further emphasizes that Euler equation tests of capital mobility may also be unreliable indicators. Yet, his results are not based on a two-country model, and he considers a particular type of quantitative restrictions on capital mobility only.

We extend the work by Mendoza (1994) and Baxter and Crucini (1993) by using a monetary two-country stochastic dynamic general equilibrium model. In addition to the impact of financial integration, we control for several factors that are likely to affect intertemporal consumption choices. Specifically, we analyze the effects of habit formation (Ferson and Constantinides 1991), of automatic fiscal stabilizers (Arreaza et al. 1998), of interest rate smoothing by central banks (Goodfriend 1991), and of inflation persistence (Fuhrer and Moore 1995) .

The structure of the paper is as follows. In the following second part, we re-establish the stylized facts of capital mobility in OECD countries, using the Euler equation test proposed by Obstfeld (1989). We also present stylized evidence on the correlation patterns of consumption and output across countries. In part three, we present the model. Part four gives the results our study regarding the properties of Euler equation tests of capital mobility. Part five concludes.

2 Euler Equation Tests of Capital Mobility: Stylized Facts from the G7 Countries

In this section, we briefly review the concept of Euler equation tests of capital mobility, and we present some stylized facts. The Euler equation test can be derived from the permanent income hypothesis, according to which households aim at establishing smooth consumption patterns over time. Consumption plans change only in response to changes in expectations concerning future income (Campbell 1987, Hall 1978). In an international context, this hypothesis has two implications. First, the move from a financially closed to a financially open economy should provide households with improved possibilities to smoothen consumption over time, since they can borrow and lend on international financial markets. Hence, consumption should become less correlated with domestic output over time. Second, differences in consumption patterns between domestic and foreign households should diminish if preferences do not differ between countries. These implications form the basis for consumption-based measures of capital mobility.

To check whether these predictions are confirmed by the data, we study stylized facts on differences in consumption patterns and on cross-country correlations of consumption and output for the G7 countries. In the G7 countries, capital account liberalization has proceeded quite rapidly during the past 40 years. According to an index which runs from 3 (restrictive capital account regime) through 1 (no capital controls), all G7 countries had direct capital controls in place in the early 1970s and had fully liberalized capital flows by the end of the century.[1] At the same time, even in these countries, some indirect restrictions to the free flow of capital in the form of, for instance, differences in institutional structures remain in place even today. Nevertheless, the substantial deregulation of capital markets that has taken place in the G7 countries in the past decades has been one key factor behind the substantial increase in global capital flows that could be observed during the 1990s.

2.1 Euler Equation Tests of Capital Mobility

In a domestic context, the consumption Euler equation postulates that the consumer's marginal rate of substitution of present for future consumption equals the price of future in terms of present consumption, i.e., the inverse of the real rate of interest, r: $\beta u'(C_2^i)/u'(C_1^i) = 1/1+r$, where β = subjective discount rate, and C = consumption. This condition can be derived by maximizing the consumer's lifetime utility subject to her lifetime budget constraint.

In an international context, the Euler equation translates into a relationship between the marginal rates of substitution at home and abroad. If households at home and abroad can invest in the same risk-free asset and have the same preferences, then their expected marginal rates of substitution between current and future consumption should be equal. Under these assumptions, differences in the marginal rates of substitution of consumption can be interpreted as evidence for incomplete

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1 More specifically, while Canada and Germany had liberalized capital flows to some extent (index value of 2), the index for all other G7 countries took a value of 3. For details on the construction of the index see Kaminsky and Schmukler (2001). Information on capital account restrictions has kindly been provided by Sergio Schmukler.

international mobility of capital (Obstfeld 1989). More formally, the Euler equation test of capital mobility is based on the notion that differences in the marginal rates of substitution should be unpredictable on the basis of information available at time t:

$$\begin{aligned} & \mathbb{E}_t\left[\left(\frac{C_t}{C_{t+1}}\right)^{\vartheta}\left(\frac{P_t}{P_{t+1}}\right)-\left(\frac{C_t^*}{C_{t+1}^*}\right)^{\vartheta}\left(\frac{S_t P_t^*}{S_{t+1}^* P_{t+1}^*}\right)\right]=\mathbb{E}_t(\eta_{t+1})=0, \\ & \mathbb{E}_t\left[\left(\frac{C_t}{C_{t+1}}\right)^{\vartheta}\left(\frac{P_t/S_t}{P_{t+1}/S_{t+1}}\right)-\left(\frac{C_t^*}{C_{t+1}^*}\right)^{\vartheta}\left(\frac{P_t^*}{P_{t+1}^*}\right)\right]=\mathbb{E}_t(\eta_{t+1}^*)=0, \end{aligned} \tag{1}$$

where P = prices, S = domestic currency price of foreign currency, $\mathbb{E}$ = expectations operator, and ϑ = the reciprocal of the intertemporal elasticity of substitution. Foreign variables are denoted by a star. In implementing the test empirically, Obstfeld (1989) proposes testing whether past differences in the marginal rates of substitution of consumption between countries help predicting current differences by running the following regression:

$$\eta_t = \gamma_0 + \sum_{i=1}^{N} \gamma_i \eta_{t-i} + V_t, \tag{1'}$$

where V = errors that are orthogonal to information set available at date t–1 or earlier, assuming alternative values for ϑ. Perfect financial integration then implies:

$$H_0: \quad \gamma_0 = 0 \quad \wedge \quad \gamma_i = 0 \quad \forall \quad i = 1,\ldots,N.$$

Table 1 presents results for these tests for the G7 countries. To implement the tests, we use quarterly data covering the period of time from 1980:1 to 2000:4 taken from the OECD's "Main Economic Indicators" CD-Rom. To estimate Eq. (1'), we compute the deviations of the time series under investigation from their respective trend. To measure the trend, we use the filter advocated by Hodrick and Prescott (1997) with a smoothing parameter of 1,600.

The F-values reported in Table 1 give the results of a test of $\gamma_i = 0$. The t-values additionally test $\gamma_0 = 0$. Generally, the test results clearly lead us to reject the hypothesis of full capital mobility. The exception is Germany. A possible explanation is that we lack pre-unification data, which may impair the reliability of our test results.

— Insert Table 1 about here. —

2.2 Cross-Country Correlation Patterns

A second stylized fact that can be used to show the degree of capital mobility is the correlation between domestic and foreign consumption. In integrated financial markets, domestic and foreign consumption should be closely correlated, and consumption correlations should exceed output correlations. Contrary to this prediction, Backus, Kehoe, and Kydland (1992, 1995) find relatively large co-movements of output across countries as well as output correlations that tend to exceed consumption correlations. (See also Baxter (1995), and Bayoumi (1999).) Using historical time series, Basu and Taylor (1999) show that there is very little co-movement in consumption between the U.S. and other countries, and they take this as evidence of a limited degree of international financial integration and thus risk-sharing.

Obstfeld (1994) has formulated an empirical test of capital mobility that is based on cross-country consumption correlations. He estimates the following equation:

$$\Delta \log C_{it} = \delta + a_{iW} \Delta \log C_{Wt} + \varepsilon_{it}, \qquad (2)$$

where $C_{it}(C_{Wt})$ = consumption in country *i* (world consumption). In integrated financial markets, $\delta = 0$ and $a_{iW} = 1$ should hold.

Within-country and cross-country correlations for the G7 countries summarized in Table 2 in general confirm the above finding that financial integration is incomplete: in the G7 countries, domestic consumption and domestic output are highly correlated. On average, correlations between domestic consumption and domestic output exceed those of domestic and foreign consumption. Also, cross-country output correlations are larger on average than cross-country consumption correlations.

— Insert Table 2 about here. —

3 Euler Equation Tests of Capital Mobility: Theoretical Framework

The previous section has re-confirmed the finding of the empirical literature that capital mobility remains incomplete even in those countries that have abolished direct controls on the free flow of capital. Both Euler equation tests as well as the stylized facts on cross-country consumption and output correlations have pointed in this direction. At least two factors could be responsible for this result. First, the actual degree of capital mobility may in fact be incomplete. Second, the model that is used to derive the Euler equation test of capital mobility might fail to capture important features of the underlying economies. If, for instance, consumption preferences are identical across countries, this could explain why domestic and foreign consumption do not move in parallel. In this case, the tests derived might be relatively uninformative with respect to the actual degree of capital mobility.

In this section, we present the general equilibrium model that we use to analyze how the specification of consumer preferences affects the properties of Euler equation tests of capital mobility. The model we use is based on the Obstfeld-Rogoff (1995) "new open economy macro" (NOEM) model and its extension developed by Sutherland (1996). Sutherland has shown how the baseline model can be extended to analyze financial market integration by assuming that international financial transactions are costly. Hence, in his model, domestic and foreign bonds become imperfect substitutes. By varying the transaction costs, one can analyze whether Euler equation tests are able to distinguish synthetic time series obtained by simulating the model under high capital mobility from those obtained under low capital mobility (see Section 4).

Because Euler equation tests are based on comparisons of cross-country consumption patterns, we control for factors that may affect these patterns. Specifically, we analyze how the specification of consumer preferences affects the performance of the Euler equation test of capital mobility. We extend the model by Sutherland (1996) in three ways to make the specification of consumer preferences more realistic. First, we acknowledge the finding of recent empirical studies (see, e.g., Fuhrer 2002) that household behavior is characterized by habit formation. Second, we add stochastic preference shocks to the model. As discussed by Stockman and Tesar (1995), such preference shocks may be important determinants of international business cycles. Third, we allow the intertemporal elasticity of substitution to differ across countries, i.e., we allow for cross-country heterogeneity in consumption preferences.

In addition to these modifications of consumer preferences, we also modify the model in order to incorporate additional factors that might affect consumption behavior in open economies. More specifically, we follow Taylor (1993) in assuming that monetary policy targets the short-term nominal interest rate rather than the money supply. This interest rate smoothing objective of the central bank (Goodfriend 1991) may affect the consumption patterns in our model because households' intertemporal consumption choices are governed by the behavior of the real interest rate. Moreover, we assume that firms set prices according to a variant of the price setting mechanism advanced by Fuhrer and Moore (1995). This addresses the empirical observation that inflation tends to be highly persistent and has implications for consumption patterns via the dynamics of the real interest rate. Finally, we add "cost push" shocks (see Clarida, Gali, and Gertler 1999: p. 1667), and we assume a fiscal policy feedback rule since, empirically, Arreaza et al. (1998) find that fiscal policy achieves a significant amount of consumption smoothing in OECD countries.

3.1 Household Preferences and Global Goods Markets

The model consists of two equally-sized countries, Home and Foreign. Each country is inhabited by infinitely-lived households. Households form rational expectations and seek to maximize their expected lifetime utility: $U_t = \mathbb{E}_t \sum_{s=t}^{\infty} \beta^{s-t} u_s$, with $0 < \beta < 1$ being the domestic household's subjective discount factor, and $\mathbb{E}_t$ denoting the conditional expectations operator. The period-utility function of a Home household is given by:

$$u_t = \exp(\kappa_t)\left(\frac{\sigma_j}{\sigma_j - 1}\right)\left(\frac{C_t}{C_{t-1}^h}\right)^{(\sigma_j - 1)/\sigma_j} + \chi\frac{(M_t / P_t)^{1-\varepsilon}}{(1-\varepsilon)} - \frac{N_t^{\mu}}{\mu}, \tag{3}$$

where $\mu > 1$, $\sigma_j > 0$ with $j \in \{H,F\}$, $\varepsilon > 0$, and $\chi > 0$ are parameters. κ_t denotes a white noise preference shock, and the habit formation parameter, h, lies in the interval $h \in [0,1)$ (see, e.g., McCallum and Nelson 1999). When simulating the model, we allow the intertemporal elasticity of substitution, σ_j, in the Home country, σ_H, to differ from its Foreign counterpart, σ_F. This, together with our assumptions that the period-utility function is subject to stochastic preference shocks, implies that we can analyze the performance of the Euler equation test of capital mobility when consumer preferences differ across countries.

In Eq. (3), C_t denotes a real consumption index, N_t is the household's labor supply, and M_t / P_t denotes the end-of-period real money holdings, where M_t is Home nominal money balances (there is no currency substitution), and P_t is the aggregate Home price index defined below. Unless indicated otherwise, all conditions derived in the following equally apply to the Foreign country, except that all Home variables are replaced with their Foreign counterparts.

Aggregate consumption, C_t, is defined as a CES aggregate over a continuum of differentiated, perishable Home and Foreign consumption goods of total measure unity. These goods are sold by Home and Foreign firms in a monopolistically competitive goods market. The aggregate consumption index is defined as

$$C_t = \left[\int_0^1 c_t(z)^{(\theta-1)/\theta} \, dz \right]^{(\theta-1)/\theta}, \tag{4}$$

where the differentiated goods are indexed by $z \in [0,1]$, $\theta > 1$, and $c(z)$ denotes consumption of good z.

The Home price deflator for nominal money balances, P_t, is defined as the minimum expenditure required to buy one unit of the aggregate consumption bundle, C_t. Assuming that the law-of-one-price holds for each differentiated good, this price deflator can be expressed as

$$P_t = \left[\int_0^1 p_t(z)^{1-\theta} \, dz \right]^{1/(1-\theta)}, \tag{5}$$

where $p_t(z)$ denotes the domestic currency price of good z. The law-of-one-price implies $p_t(h) = S_t \, p_t^*(h)$ and $p_t(f) = S_t \, p_t^*(f)$, where $p_t(f)$ = Home currency price of a Foreign good and $p_t^*(h)$ = Foreign currency price of a Home good. With identical preferences, purchasing power parity holds as well: $P_t = S_t P_t^*$, where P_t^* denotes the aggregate foreign price level and S_t denotes the nominal exchange rate (price of foreign in terms of domestic currency).

3.2 International Financial Linkages

When taking positions in international financial markets, households have to take into account that financial markets are not perfectly integrated. Following Sutherland (1996), we assume that Home households have free access only to the domestic capital market. When transferring funds to the Foreign capital market, they incur intermediation costs:

$$Z_t = 0.5\psi_1 I_t^2 + 0.5\psi_2[(F_t - \overline{F})/P_t^*]^2, \qquad (6)$$

where $\psi_1 > 0$ and $\psi_2 > 0$ are positive constants, F_t = stock of foreign currency denominated assets held by Home households, $\overline{F}$ = steady state level of the foreign asset holdings of Home households, and I_t = level of real funds transferred by Home households from the Home to the Foreign bond market (Z_t and I_t are denominated in terms of the consumption aggregate, C_t).

The first term on the right-hand side of Eq. (6) can be thought of as representing portfolio adjustment costs arising when households carry out cross-border financial transactions. The second term on the right-hand side of Eq. (6) denotes quadratic costs of holding a quantity of foreign bonds different from its long-run steady state level. This second term ensures that the foreign asset position and, thus, the steady state around which the model is log-linearized is stationary. (See Schmitt-Grohe and Uribe (2001) for a further discussion of this point.)

3.3 Households' Budget Constraints

Households receive interest income for holding Home and Foreign bonds, profit income from domestic firms, and labor income. In addition, they pay taxes and incur intermediation costs when undertaking positions in the international bond market. The dynamics of Home households' domestic bond holdings can, thus, be described by the following flow budget constraint:

$$D_t = (1 + R_{t-1})D_{t-1} + M_{t-1} - M_t + w_t N_t - P_t C_t - P_t I_t - P_t Z_t + \Pi_t - P_t T_t, \qquad (7)$$

where D_t = quantity of Home currency denominated bonds, R_t = nominal interest rate on Home bonds between period t and $t+1$, T_t = real lump-sum taxes (expressed in terms C_t), w_t = nominal wage rate earned in a perfectly competitive

Home labor market (there is no possibility of migration across countries), and Π_t = nominal profit income the household receives from Home firms.

The dynamics of Home households' Foreign bond holdings are given by:

$$F_t = (1+R_{t-1}^*)F_{t-1} + P_t^* I_t \,, \tag{8}$$

where R_t^* = nominal foreign interest rate paid for holding a foreign bond between period t and $t+1$.

3.4 First-Order Conditions

The first-order conditions for Home households' optimal consumption choices, money holdings, labor supply, and Home and Foreign bond holdings are given by

$$\exp(\kappa_t)(1/C_{t-1}^h)^{(\sigma_H-1)/\sigma_H} C_t^{-1/\sigma_H} - \beta h C_t^{(h-h\sigma_H-\sigma_H)/\sigma_H} \mathbb{E}_t(\exp(\kappa_{t+1})C_{t+1}^{(\sigma_H-1)/\sigma_H}) = \lambda_t P_t \,, \tag{9}$$

$$\chi(M_t/P_t)^{-\varepsilon} + \beta P_t \mathbb{E}_t(\lambda_{t+1}) = \lambda_t P_t \,, \tag{10}$$

$$N(z)^{\mu-1} = \lambda_t w_t \,, \tag{11}$$

$$(1+R_t)\beta \mathbb{E}_t(\lambda_{t+1}) = \lambda_t \,, \tag{12}$$

$$\begin{aligned} &\lambda_t S_t - \beta(1+R_t^*)\mathbb{E}_t(\lambda_{t+1}S_{t+1}) + \psi_1\lambda_t S_t + \psi_2\lambda_t S_t(F_t-\overline{F})/P_t^* \\ &= \beta(1+R_t^*)\psi_1 \mathbb{E}_t(\lambda_{t+1}S_{t+1}I_{t+1}) \end{aligned} \,, \tag{13}$$

where λ_t denotes the Lagrange multiplier. We assume that the usual transversality condition applies. Eq. (13) shows that the intermediation costs for undertaking cross-border financial transactions ($\psi_1 > 0$, $\psi_2 > 0$) drive a wedge between domestic and foreign interest rates. Also, if we invoke some restrictions on the parameters and preferences, the Euler equation test given in Eq. (1) drops out of our general equilibrium model.[2] Upon adding habit formation, preference shocks, and international transaction costs, we can thus study how reliable the Euler equation test of

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2 More specifically, if $h=0$, $\kappa_t = 0$ for all t, and $\psi_1 = \psi_2 = 0$, Eqs. (9), (12), and their foreign counterparts can be combined to obtain the Eq. (1), where $\vartheta \equiv 1/\sigma$ with $\sigma = \sigma_H = \sigma_F$.

capital mobility is as an indicator of international capital mobility if the assumptions on households' preferences used to derive Eq. (1) are not satisfied.

3.5 Price Setting

Each country is populated by a continuum of firms producing differentiated products. As is standard in this literature, the capital stock is fixed, and the only production factor used by the firms is labor. The production function for a Home firm is given by $y_t(z) = N_t(z)$, implying that the nominal profit income of firm z is given by $\Pi_t(z) = p_t(z)y_t(z) - w_t y_t(z)$. Firms hire labor in a perfectly competitive, internationally segmented, labor market.

Each firm treats the price it charges for its differentiated product as a choice variable but firms incur menu costs when changing their price. To model this price-stickiness, we assume a price-adjustment mechanism similar to the one introduced by Fuhrer and Moore (1995) (see also McCallum and Nelson 2000). This assures an empirically reasonable degree of inflation persistence.

More specifically, the rate of change of the price index of the Home produced goods is a function of the output gap, $\hat{y}_t$ (defined as the deviation of actual output from its long run flexible price steady state level), and of the weighted arithmetic average of the lagged and expected price changes:

$$d\hat{p}(h)_t = \alpha d\hat{p}(h)_{t-1} + (1-\alpha)\, \mathbb{E}_t d\hat{p}(h)_{t+1} + \Psi \hat{y}_t + \varepsilon_{p,t}, \qquad (15)$$

where $\alpha \in [0, 1]$, Ψ is a positive constant, $\varepsilon_{p,t}$ is a stochastic disturbance term (a "cost push" shock), and variables with a hat denote percentage deviations from the steady state.

Given the price of the differentiated goods, the quantities produced by the firms can be derived from the demand function for their respective good:

$$y_t(h) = \left[p_t(h) / P_t\right]^{-\theta} Q_t, \qquad (16)$$

where $Q_t = nC_t + (1-n)C_t^* + nG_t + (1-n)G_t^* + nZ_t + (1-n)Z_t^*$ is the aggregate world goods demand.

3.6 Monetary and Fiscal Policy

The central bank sets the nominal interest rate in response to deviations in aggregate inflation and in the output gap from their target levels (Taylor 1993):

$$\hat{R}_t = \mu_0 + (1-\mu_3)[d\hat{P}_t + \mu_1(d\hat{P}_t - \overline{\pi}) + \mu_2\hat{y}_t] + \mu_3\hat{R}_{t-1} + \varepsilon_{R,t}\,, \qquad (17)$$

where $\varepsilon_{R,t}$ is a serially uncorrelated stochastic monetary policy shock, $\overline{\pi}$ is the inflation target of the central bank, and μ_1 and μ_2 are parameters that capture the reaction of the central bank to inflation deviations and to the output gap. The parameter μ_3 captures the interest rate smoothing objective of central banks (Goodfriend 1991).

Fiscal authorities collect lump-sum taxes and use them together with seignorage revenues to finance real government purchases, G_t (denominated in terms of the consumption index, C_t):

$$P_tG_t = P_tT_t + M_t - M_{t-1}\,. \qquad (18)$$

Real government spending is determined by a fiscal policy feedback rule. This feedback rule is a stochastic process describing the dynamics of G_t as a function of lagged real government spending and of the current output gap (Taylor 2001):

$$\hat{G}_t = \rho_{G,1}\hat{G}_{t-1} + \rho_{G,2}\hat{y}_t + \varepsilon_{G,t}\,. \qquad (19)$$

where $\rho_{G,i} \in \{1,2\}$, $i = 1,2$ are parameters, and $\varepsilon_{G,t}$ is a stochastic innovation term. The parameter $\rho_{G,2}$ captures the impact of automatic stabilizers on government spending.

3.7 Definition of Equilibrium and Model Solution

Before deriving the implications of the above model for Euler equation-based tests of capital mobility, we need to specify the equilibrium conditions and to solve the model. In a symmetric equilibrium, the endogenous variables (output, consumption, the exchange rate, prices, interest rates, wage rates, bond holdings) follow processes such that (i) the labor market in each country clears, (ii) the optimality conditions for consumption and asset holdings are satisfied, (iii) the intertemporal budget constraint for each country is satisfied, (iv) the markets for domestic and foreign bonds are in equilibrium, and (v) inflation dynamics and central bank policy satisfy Eqs. (14) and (19) (and their Foreign counterparts), respectively.

To determine the equilibrium paths of the endogenous variables, we solve the model numerically. In a first step, we calibrate the model, following the literature as closely as possible. Most of the parameters are standard and are as given in Sutherland (1996). Table 3 gives our benchmark calibration of the model. In this benchmark calibration, we assume that the intertemporal elasticity of substitution, σ, is identical across countries. We will relax this assumption in Section 4.

— Insert Table 3 about here. —

In a second step, we log-linearize the model around a symmetric flexible-price steady state in which the Home and Foreign foreign asset positions are zero (Obstfeld and Rogoff 1995). We use the log-linear version in our numerical simulations of the model, and we assume that the stochastic innovation terms, $\varepsilon_{j,t}$, $j \in \{R, G, k, P\}$ driving the Home and Foreign economies are uncorrelated.[3]

3.8 Properties of the Model

This section checks whether our model mimics some key properties of real-world business cycles. To this end, we run stochastic simulations of the model and compare the simulated moments with the empirical moments of the corresponding real-world time series.

The simulated moments for output and consumption and the corresponding empirical moments we observe in the data for the G7 countries are given in Tables 4 and 5. We present results for both a model with high and a model low international capital mobility. In addition, we present the empirical and theoretical standard deviations and autocorrelations.

— Insert Tables 4 and 5 about here. —

The model fits the data for the G7 countries fairly well in several dimensions (Table 5). The standard deviations of output and consumption implied by the model are larger than those for the G7 countries. Yet, when compared with the standard devia-

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3 We use Paul Klein's algorithm "solve.k" in Matlab (Klein 2000). This solution determines the paths of the endogenous variables in terms of the predetermined and exogenous state variables.

deviations of output for individual G7 countries like Canada or the U.K. (Table 4), the standard deviations implied by the model are not unreasonably high.

The autocorrelation of output in the model fits the autocorrelation of output observed in the G7 data very well. This is especially true under the assumption of low capital mobility. The autocorrelation of consumption in the model is slightly larger than the autocorrelation of consumption in the data.

With respect to the within-country correlation of consumption with GDP, the predictions of the model are in line with the output-consumption correlation in the real-world data. Again, the model fits particularly well if we consider a world economy with a low degree of international capital mobility.

While the average cross-country GDP correlation among the G7 countries is positive, the cross-country output correlation implied by our model is negative. Thus, in this respect, our model has the same property as many other international business cycle models. The simulation results for the cross-country correlations of consumption are somewhat better. As in the data, the cross-country consumption correlations implied by the model are positive. Moreover, the magnitudes of the simulated cross-country consumption correlations are comparable to those we observe in the data. As expected, the cross-country consumption correlations implied by the model tend to be higher under high capital mobility than under low capital mobility. Essentially, this is the stylized fact on which the Euler equation test of capital mobility suggested by Obstfeld (1986) is based.

4 The Properties of Euler Equation Tests of Capital Mobility

In this section, we use a simulation-based study to analyze whether, under alternative assumptions regarding consumer preferences, the Euler equation test is able to distinguish data that have been generated using a model with high capital mobility from a model with low capital mobility. Good performance of the test on the basis of the simulated data would strengthen our confidence that differences in test results based on real-world data are indicative of the actual degree of capital mobility.

4.1 Simulation Design

To set up our simulation-based study, we proceed as follows. We simulate various versions of the model. For each version, we perform 1,000 stochastic simulations runs. Each simulation run consists of 100 observations. This is also roughly the number of observations we used in Section 2 to estimate Euler equations for the G7 countries. In order to assess how the properties of the Euler equation test depend upon the model specification, we analyze the following six versions of the model:

In Version 1, we analyze the power of the Euler equation test to discriminate between high and low capital mobility by setting $\psi_1 = 5.0$ and $\psi_1 = 0.0$, respectively. We rule out habit formation and preference shocks ($h = 0$ and $\kappa_t = 0$). Such a specification of preferences is closest in spirit to the model underlying the standard Euler equation test discussed in Section 2.

In Version 2, we allow for habit formation and preference shocks. We set $h = 0.8$ and assume that preference shocks are i.i.d. for all t. We use the simulation results for Version 2 to assess how the baseline Euler equation test derived by using a model featuring iso-elastic household utility performs when the actual data generating process embeds habit formation and preference shocks.

In Version 3, we analyze how the costs of holding international asset positions (ψ_2) influence our results. In our model, setting $\psi_1 = 0.0$ does not imply that international financial markets are perfectly integrated but rather that capital *flows* carry no costs. Yet, countries bear costs if they accumulate high *stocks* of foreign assets. Thus, allowing for $\psi_2 > 0$ renders it possible to analyze how the Euler equation test performs under the (realistic) assumption that global capital markets are highly but still not perfectly integrated. In Version 3 of the model, we take a further step towards international financial market integration by changing ψ_2 from $\psi_2 = 0.05$ to $\psi_2 = 0.005$.

In Version 4, we take into account that in the empirical applications of the Euler equation test of capital mobility, a numerical value is assigned to the households' intertemporal elasticity of substitution to construct the variable η_t used in Eq. (1'). Here, we invoke the realistic assumption that the econometrician does not have exact a priori knowledge of the households' intertemporal elasticity of substitution. We proceed in two steps. In a first step, we simulate Version 1 of our model. In these simulations, the true theoretical intertemporal substitution elasticity assumes the numerical value 1.3 (corresponding to $\sigma_H = \sigma_F = 0.75$). In a second step, we use the simulated data and an arbitrary (wrong) intertemporal substitution elasticity of 2.0 to implement the Euler equation test of capital mobility.

In Version 5, we allow for differences in the intertemporal elasticity of substitution across countries. Specifically, we set $\sigma_H = 1.0$ (so that Home consumers have a logarithmic period-utility function) and $\sigma_F = 0.25$. Again, we assume that the econometrician does not have a priori knowledge of the differences between Home and Foreign households' intertemporal elasticity of substitution, and we set $\sigma_H = \sigma_F = 0.75$ to construct η_t.

In Version 6, we allow (as in Version 5) for differences in the intertemporal elasticity of substitution across countries and additionally allow for habit formation and stochastic preference shocks. As in Version 2, we set $h = 0.8$ and assume that preference shocks are i.i.d. for all t. Thus, in Version 6 we assume that consumer preferences both differ across countries and differ from the simple iso-elastic period-utility function used to derive Eq. (1').

Having simulated the various versions of the model, we take the anti-logs of the simulated time series and implement the Euler equation test of international capital mobility based on Eq. (1). To test for the degree of international capital mobility, we use a *t*-test and an *F*-test to test the null hypotheses, $\gamma_0 = 0$ and $\gamma_i = 0$ for $i = 1,...,N$ (see Eq. (1')). We set $N = 2$. We store the results of the *F*-tests to get 1,000 test results, and we use relative frequency distributions to visualize our results.

4.2 Sampling Distributions

We plot the relative frequency distributions (i.e., sampling distributions) of the *F*-tests we obtain for the various versions of our model in Figure 1. We plot the sampling distributions we obtained for models with high (low) capital mobility on the left (right). We plot in Panel A the sampling distribution for Version 1 of our model and in Panel B through F the sampling distributions we obtain for Version 2 through 6, respectively.

— Insert Figure 1 about here. —

For all versions of our model, the Euler equation test turns out to be relatively reliable indicator of the degree of international capital mobility (Figure 1). The mean of the sampling distributions on the left-hand side is substantially smaller than the mean of the sampling distributions on the right-hand side. Moreover, the probability mass concentrated around the mean is larger in the high-capital mobility versions than in the low-capital mobility version of the model, i.e., the standard deviation of the sampling distribution of the *F*-test is smaller for the former.

Comparing Panels A and B further shows that the test seems to be relatively robust with respect to the specification of the utility function. Panel B demonstrates that the Euler equation test given in Eq. (1') discriminates, albeit less sharply than in Panel A, between the high and the low capital mobility regime even though we have added habit formation and preference shocks to household preferences. Although we neglect habit formation and preference shocks when estimating Eq. (1'), there are still substantial differences between the *F*-tests.

Comparing the left-hand sides of Panels C and A shows that lowering the second component of the transaction costs for undertaking positions in international financial markets results in a moderate leftward shift of the *F*-tests. Also, because the numerical value given to the parameter ψ_2 is relatively small, the sampling distribution of the F-test indicates that the probability of observing a relatively low *F*-test is relatively large even in the low-capital-mobility case. In particular, the magnitude of the largest *F*-tests is smaller in the left-hand side of Panel C than in the left-hand side of Panel A.

The simulation results summarized in Panel D indicate that the distribution of the *F*-test seems to be relatively robust with respect to misspecifications of households' intertemporal elasticity of substitution. Thus, even if, in empirical applications, the econometrician does not have an exact a priori knowledge of this substitution elasticity, there are still substantial differences between the sampling distributions of the *F*-test in a world of high and low capital mobility. The message conveyed by the sampling distributions given in Panel E and Panel F is similar: the *F*-test is relatively insensitive to the erroneous assumption that cross-country differences in households' intertemporal elasticity of substitution are identical.

This confirms the general message conveyed by the sampling distributions: the *F*-test reacts quite sensitively to changes in the degree of international capital mobility, suggesting that Euler equation tests should yield a fairly reliable estimate of international financial integration. This result helps to build up confidence in the results of empirical studies using Euler equation tests of international capital mobility. Yet, Panel F also suggests that if the econometrician is wrong in assuming that the intertemporal elasticity of substitution is identical across countries and, in addition, neglects habit formation and preference shocks, then the probability of obtaining a very low *F*-test decreases to a non-negligible extent. Hence, as expected, the larger are the differences between real-world consumer preferences and the consumer preferences used to derive the Euler equation test, the lower is the power of the test.

4.3 Some Evidence on the Size of the Test

A somewhat different question is how closely the simulated sampling distributions of the Euler equation test mimick an *F*-distribution. To answer this question, we use the data on the *F*-tests plotted in Figure 1 to study how often the null hypothesis of financial market integration is rejected at a marginal significance level of 5 percent. To this end, we compare the results of the *F*-tests applied to our simulated data with the critical values of the *F*-distribution. Because the null hypothesis of the *F*-test stipulates that financial markets are integrated, we focus on those versions of the model featuring high capital mobility.

As can be seen in Table 6, in Versions 2 and 3, the simulated sampling distributions approximates the theoretical *F*-distribution fairly well. In the case of Version 3, this comes at no surprise, since the assumptions regarding households' utility function closely matches the assumptions needed to derive the Euler equation given in Eq. (1'). In all the other versions of the model, the relative frequency of sufficiently small simulated *F*-values falls short of the theoretical probability of obtaining such very small *F*-values. This, of course, reflects the fact that we are considering versions of the model in which some (indirect) costs of cross-border transaction prevail under the null hypothesis. In consequence, the probability of getting very small test results, which indicate perfect capital mobility, is smaller than indicated by the theoretical *F*-distribution.

— Insert Table 6 about here. —

This result suggests that the nominal size of the test may differ from the theoretical size if the assumptions of the model underlying Eq. (1) are not satisfied in empirical applications of Euler tests of capital mobility. It, thus, seems worthwhile to use, e.g., Monte Carlo or boostrapping techniques to generate confidence bands when using these tests.

5 Conclusions

How integrated are international financial markets? Obtaining a reliable answer to this question is important for a number of policy areas, including monetary policy, fiscal policy, or banking supervision. At the same time, many popular measures of capital mobility have been criticized for being not very robust with regard to changes in the structural parameters of the underlying model, for lacking a benchmark of financial integration, or for lacking a solid theoretical foundation. The consumption-based Euler equation test of capital mobility avoids of these problems, in particular because it is derived from an explicit optimization framework.

In this paper, we have investigated the performance of Euler equation tests of capital mobility in a general equilibrium framework. The natural candidate for studying the performance of these tests is a new open economy macro model in the tradition of Obstfeld and Rogoff (1995), since the model is explicitly built around the intertemporal consumption smoothing properties of the current account.

We have used this model to analyze how the specification of consumer preferences affects the reliability of Euler equation tests of capital mobility. We have extended the model to incorporate habit formation, preference shocks, and differences across countries with respect to the intertemporal substitution elasticity. In addition, we have modified the model by allowing for factors that affect intertemporal consumption choices such as automatic fiscal stabilizers, interest rate smoothing, and inflation persistence.

Although we have departed from the baseline model in which the Euler equation test was originally derived, we find that the test discriminates quite well between artificial data which have been derived under assumptions of low versus high capital mobility. Hence, differences in test results across countries are indeed indicative of differences in the degree of financial integration.

Our results should not be interpreted to suggest that the Euler equation test is a good measure of international capital mobility under all circumstances. Rather, if the general equilibrium model we have used in our analysis provides a reasonable approximation of some key features of real-world economies, then the Euler equation test is relatively robust to misspecifications of households' preferences in empirical research. Because all of our results are, unfortunately but inevitably, model-dependent, it would be particularly important to understand whether and, if so, how the results reported in this paper must be modified when our model is extended to incorporate additional features of real-world economies. For example, it would be worthwhile to study how sensitive Euler equation tests of capital mobility are with respect to the specification of household preferences when goods markets are imperfectly integrated or when there are financial market frictions. It would also be important to explore in future research how the introduction of the accumulation of capital affects the results we have derived in this paper. We think that the framework we have used in this paper should provide a useful modeling platform for undertaking such research.

6 References

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Table 1 — Euler Equation Tests on Financial Integration

The table gives the results of estimating Eq. (1') for the G7 countries. To estimate this equation, we generally use quarterly data covering the period of time from 1980:1 to 2000:4. The data were taken from the OECD's "Main Economic Indicators" CD-Rom. The sample for which data are available differs from country to country. The sample periods for the individual countries for which data are not available for the entire sample period are as follows: Canada: 1981:1 – 2000:4; Italy, Japan, and U.K.: 1980:4 – 2000:4; Germany: 1991:4 – 2000:4. The data we use in the estimations are the natural logarithms of the OECD data. The Hodrick and Prescott (1997) with a smoothing parameter of 1,600 was used to remove the trend from the data.

U.S. versus...	F-value	p-value	t-value	p-value
Canada	10.01	0.00	2.48	0.02
France	3.33	0.00	2.03	0.05
Germany	0.23	1.00	1.39	0.17
Italy	3.36	0.00	2.21	0.03
Japan	2.28	0.00	2.59	0.01
UK	2.37	0.00	2.01	0.05

Table 2 — Correlations of Output and Consumption in G7 Countries

The table gives the contemporaneous correlation of consumption with output (GDP). The statistics are based on logged and H-P-filtered quarterly data for the period 1980:1 – 2001:3.

Country	Correlation of domestic consumption with domestic output	Correlation of domestic output with U.S. output	Correlation of domestic consumption with U.S. consumption
Canada	0.894	0.804	0.710
France	0.747	0.084	0.161
Germany	0.306	0.225	0.189
Italy	0.720	0.353	–0.193
Japan	0.525	0.029	–0.088
U.K.	0.822	0.508	0.655
U.S.	0.820	1.000	1.000
∅	*0.691*	*0.429*	*0.348*

Table 3 — The Calibrated Parameters

The habit persistence parameter is taken from Fuhrer (2002). The monetary policy rule and the money supply and preference shocks are calibrated as in McCallum und Nelson (1999). The parameter capturing the impact of automatic stabilizers on government spending is taken from Taylor (2001). The autoregressive coefficient in the fiscal policy reaction function and the standard deviation of the fiscal policy shock are slightly smaller than in Chari et al. (1995) who do not model the role of automatic stabilizers for government spending. The other parameters are as in Sutherland (1996).

Parameter	Value	Description
α	0.5	Weight on lagged inflation in the price setting equation
β	1/1.05	Subjective discount factor
σ	0.75	Intertemporal elasticity of substitution
θ	6.0	Intratemporal elasticity of substitution
ε	9.0	Elasticity of utility from real balances
μ	1.4	Labor supply elasticity
h	0.8	Habit persistence parameter
ψ_1	5.0 (0.0)	First component of costs for undertaking positions in international financial market in the case of low (high) capital mobility
ψ_2	0.05	Second component of costs for undertaking positions in international financial market
$\rho_{G,1}$	0.95	Autoregressive coefficient of the fiscal policy process
$\rho_{G,2}$	–0.50	Autoregressive coefficient of the fiscal policy process
σ_G	0.01	Standard deviation of fiscal policy shock
ρ_R	0.0	Autoregressive coefficient of the money supply process
σ_R	0.01	Standard deviation of monetary policy shock
ρ_κ	0.0	Autoregressive coefficient of preference shock
σ_κ	0.01	Standard deviation of the preference shock
ρ_k	0.0	Autoregressive coefficient of the price setting shock
σ_k	0.01	Standard deviation of the price setting shock
μ_1	0.5	Weight on inflation in the monetary policy rule
μ_2	0.25	Weight on the output gap in the monetary policy rule
μ_3	0.8	Interest rate smoothing parameter in the monetary policy rule

Table 4 — Standard Deviations and Auto-Correlations in G7 Countries

The table gives the standard deviations and the first-order autocorrelations of output (GDP) and consumption. The statistics are based on logged and H-P-filtered quarterly data for the period 1980:1 – 2001:3.

Country	GDP	Consumption
	Standard deviations	
Canada	1.673	1.328
France	0.878	0.823
Germany	0.757	0.754
Italy	0.953	1.367
Japan	1.128	0.946
U.K.	1.314	1.470
U.S.	1.360	1.084
∅	*1.152*	*1.110*
	Autocorrelations	
Canada	0.906	0.854
France	0.874	0.722
Germany	0.582	0.167
Italy	0.847	0.925
Japan	0.727	0.121
U.K.	0.905	1.470
U.S.	0.863	1.084
∅	*0.815*	*0.763*

Table 5 — Simulation Results

The table gives the standard deviations and the first-order autocorrelations of Home output, and Home consumption. All variables are measured in terms of deviations from the steady state. The table reports standard deviation and persistence measures averaged over 100 simulation runs, with each simulation run pertaining to a sample consisting of 100 observations. For the benchmark simulation, we set: $\alpha = 1.0$, $\rho_{G,2} = \mu_3 = 0.0$, $\psi_2 = 5.0$. For the other simulations reported in the table, we use the numerical parameter values reported in Table 1.

	Data	Low Capital Mobility	High Capital Mobility
		Standard deviations	
Output	1.152	1.857	1.571
Consumption	1.110	1.978	1.974
		Autocorrelations	
Output	0.815	0.857	0.571
Consumption	0.763	0.978	0.974
		Correlations with output	
Output	1.000	1.000	1.000
Consumption	0.691	0.726	0.419
		Correlation with the same foreign variable	
Output	0.263	–0.127	–0.662
Consumption	0.550	0.150	0.240

Table 6 — Test Results

The table gives the respective simulated probabilities of rejecting the null hypothesis (H_0) that international financial markets are integrated for the six versions of the model described in Section 4 and in Figure 1. Rejection of the null hypothesis is based on a comparison of the results of the F-tests computed for the simulated data with the respective 5 percent critical value of the theoretical F-distribution.

Version	1	2	3	4	5	6
Reject H_0	14.515	6.306	4.905	15.015	21.321	10.511

Figure 1 — Simulated Sampling Distributions of the F-Test

The figure graphs the simulated sampling distribution of the *F*-test of the null hypothesis that the coefficients on the lagged regressors in Eq. (1') are equal to zero: $\gamma_i = 0$, $i = 1,2$. The sampling distributions are obtained upon simulating the model 1000 times with each simulation run consisting of 100 observations. The versions of the model analyzed are the following:

Version 1: $\psi_1 = 5.0$ (low capital mobility); $\psi_1 = 0.0$ (high capital mobility); $h = 0$ (no habit formation); $\kappa_t = 0$ for all t (no preference shocks).

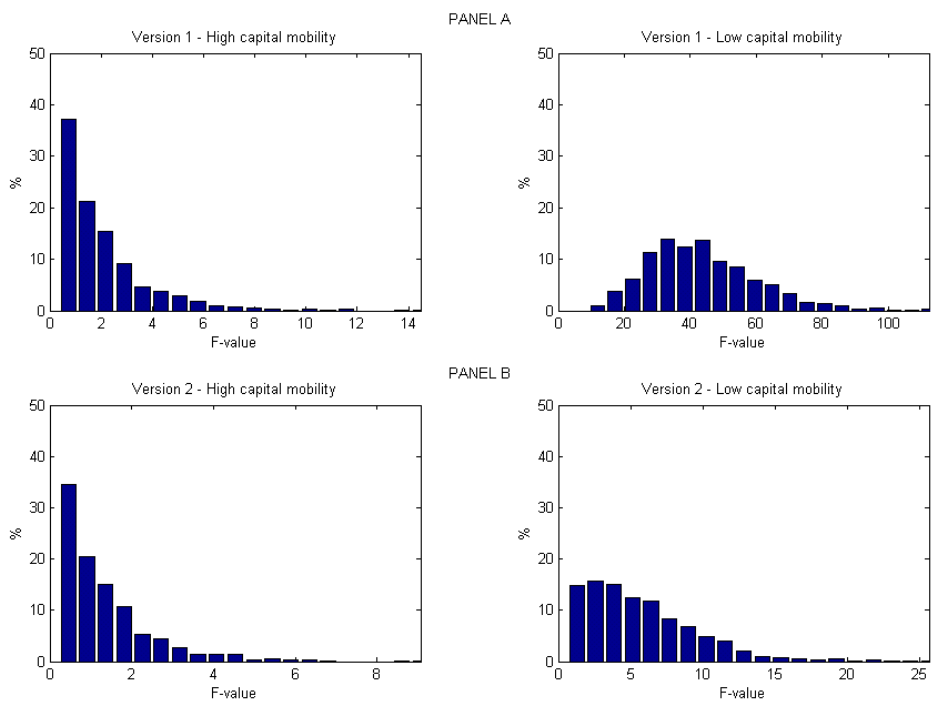
Version 2: $\psi_1 = 5.0$ (low capital mobility); $\psi_1 = 0.0$ (high capital mobility); $h = 0.8$ (habit formation); κ_t is an i.i.d. shock.

Version 3: $\psi_1 = 5.0$ and $\psi_2 = 0.005$ (high capital mobility); $\psi_1 = 0.0$ (low capital mobility); $h = 0$ (no habit formation); $\nu = 0$ for all t (no preference shocks).

Version 4: $\psi_1 = 5.0$ (low capital mobility); $\psi_1 = 0.0$ (high capital mobility); $h = 0$ (no habit formation); $\nu = 0$ for all t (no preference shocks); the intertemporal substitution elasticity is assumed to be unknown to the econometrician; the true theoretical intertemporal substitution is 1.3 (corresponding to $\sigma = 0.75$) and the intertemporal substitution elasticity used to construct η_t used in Eq. (1) is 2.0.

Version 5: $\psi_1 = 5.0$ (low capital mobility); $\psi_1 = 0.0$ (high capital mobility); $h = 0$ (no habit formation); $\kappa_t = 0$ for all t (no preference shocks); $\sigma_H = 1.0$, $\sigma_F = 0.5$; the true intertemporal substitution elasticity is assumed to be unknown to the econometrician; the intertemporal substitution elasticity used to construct η_t used in Eq. (1) is 1.3 (corresponding to $\sigma = 0.75$).

Version 6: $\psi_1 = 5.0$ (low capital mobility); $\psi_1 = 0.0$ (high capital mobility); $h = 0.8$ (habit formation); κ_t is an i.i.d. shock; $\sigma_H = 1.0$, $\sigma_F = 0.5$; the true intertemporal substitution elasticity is assumed to be unknown to the econometrician; the intertemporal substitution elasticity used to construct η_t used in Eq. (1) is 1.3 (corresponding to $\sigma = 0.75$).



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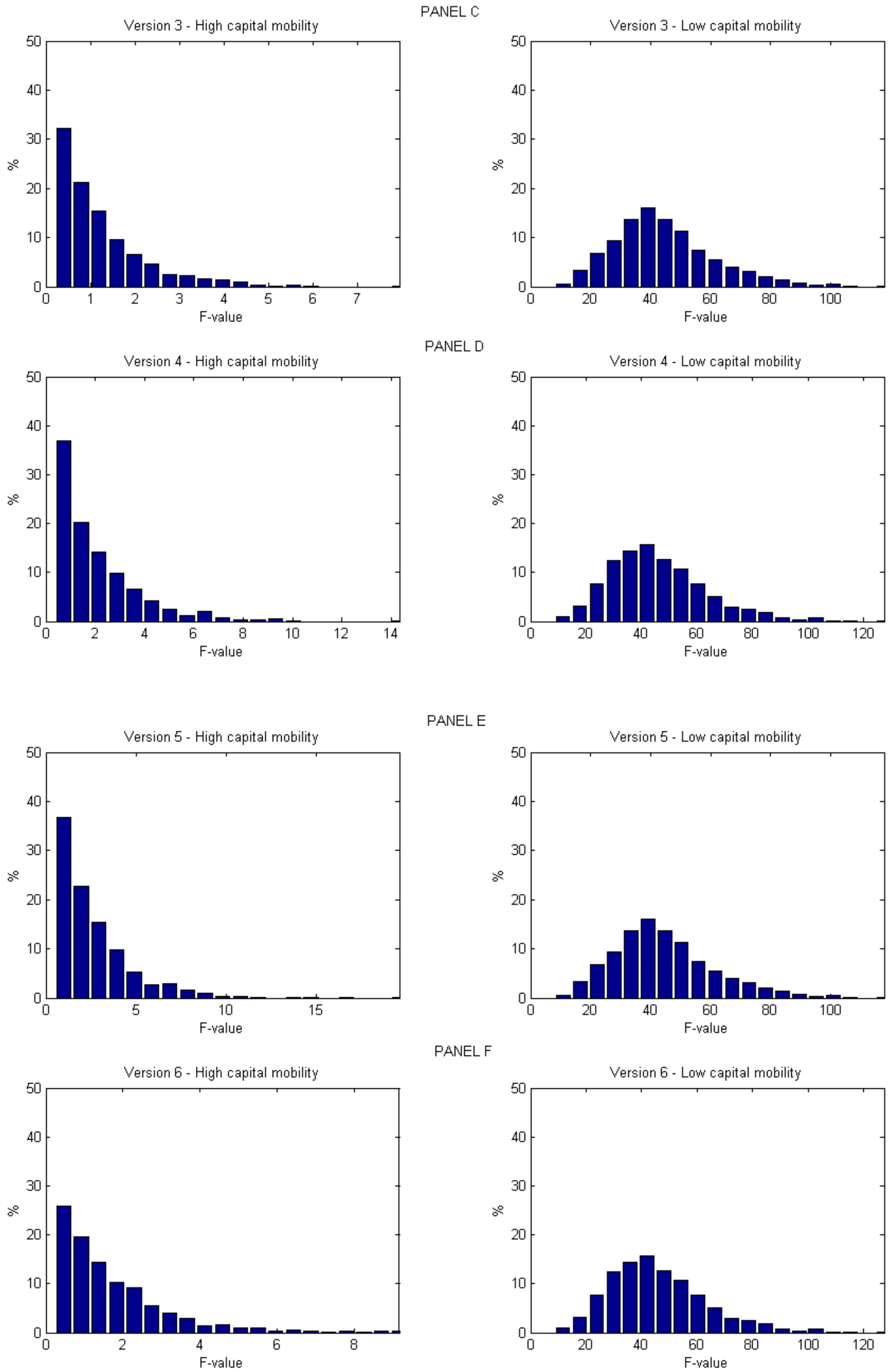
PANEL C
Version 3 - High capital mobility
Version 3 - Low capital mobility
PANEL D
Version 4 - High capital mobility
Version 4 - Low capital mobility
PANEL E
Version 5 - High capital mobility
Version 5 - Low capital mobility
PANEL F
Version 6 - High capital mobility
Version 6 - Low capital mobility
%
F-value