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# Globalization, the Volatility of Intermediate Goods Prices, and Economic Growth<sup>§</sup>

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We set up a dynamic stochastic model of a stylized economy comprising a final output sector (with traditional and modern firms) and an intermediate goods sector. It is shown that market integration reduces the volatility of the rate of return of capital invested in modern firms. The induced portfolio decision of households leads to a reallocation of capital from traditional to modern firms. Despite the presence of a reverse precautionary saving channel, the growth rate unambiguously increases due to the reallocation of capital. Empirical estimates for OECD countries confirm the theoretical results.

*Keywords:* Globalization, trade in intermediate goods, portfolio decisions, economic growth.

*JEL Classification:* F1; O4.

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# 1 Introduction

The question whether and how globalization affects economic growth is one of the most fundamental questions in economics. For a long time, there seemed to be a consensus that market integration is unambiguously good for growth (Dollar, 1992; Edwards, 1998). However, after having reexamined the bulk of recent empirical evidence, Rodríguez and Rodrik (2000) conclude that one should be sceptical about a generally positive relationship. They do not deny that market integration may affect economic growth favorably. Instead, it is argued that the openness growth nexus is quite complex and, therefore, in-depth research aimed at the identification of specific channels is called for. We follow this suggestion. First, at the level of theoretical research we investigate a specific channel which highlights the general importance of intermediate goods as a chain link in the globalization growth nexus. Second, we subject the impact of intermediate goods price volatility on growth to econometric testing, using data on intermediate goods prices and economic growth for OECD countries from 1960 to 2000.

There are a number of important reasons to highlight the significance of intermediate goods when trying to understand better the relationship between goods market integration and economic growth:

First, it is well known that the importance of goods trade relative to output in major OECD countries rose substantially during the last three decades.<sup>1</sup> Moreover, trade in intermediate goods is quantitatively substantial. The average share of trade in intermediate goods to overall goods trade for major OECD countries during the last three decades was about 50 % (Kleinert, 2003). This number has been remarkably stable. As a result, the relative importance of imported inputs in production has increased steadily as documented in Campa and Goldberg (1997).<sup>2</sup>

Second, data from the OECD input output tables (OECD, 2004) show that the share of intermediate goods in production ranges from 19% to 82% across different sectors; the median is at 57%.<sup>3</sup> This variation indicates that intermediate goods are extremely important in some sectors and of minor importance in other sectors. Based on this stylized fact, we will distinguish between modern final output firms (which produce intermediate goods intensive) and traditional final output firms (which use the second input factor, capital, intensively).

Third, a large number of endogenous growth models assign intermediate goods a

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<sup>1</sup>This can be readily seen by inspecting the series "openness" for OECD economies available from the Penn World Tables.

<sup>2</sup>Campa and Goldberg focus on major industrialized economies.

<sup>3</sup>The numbers refer to averages over the 6 major OECD countries in 1995.

prominent role in the production process. Especially important in this context are the gains from specialization. By combining intermediate goods with other input factors (capital and labor), firms can take advantage of specialization. As a consequence, the productivity of capital and labor increases (e.g. Romer 1990; Grossman and Helpman, 1991, chapter 3). Moreover, the use of intermediate goods enables an additional roundaboutness in production (von Böhm-Barwerk, 1921), which might increase the productivity of the complementary factors.<sup>4</sup>

Fourth, there is empirical evidence for a negative partial correlation between openness and the volatility of intermediate goods prices, as illustrated by the scatter plot shown in Figure 1 (a). The respective points show combinations of (adjusted) openness (*open\_adj*) and the (adjusted) volatility of intermediate goods prices (*igpvol\_adj*), as resulting from an estimation which regresses the volatility of intermediate goods prices on openness, controlling for other variables.<sup>5</sup> The observations are panel data (averages over 5 years subperiods) for 9 OECD countries from 1960 to 2000. The estimated coefficient, as illustrated in Figure 1 (a), is negative and statistically significant across different empirical specifications. This piece of empirical evidence indicates that market integration tends to lower the volatility of intermediate goods prices.

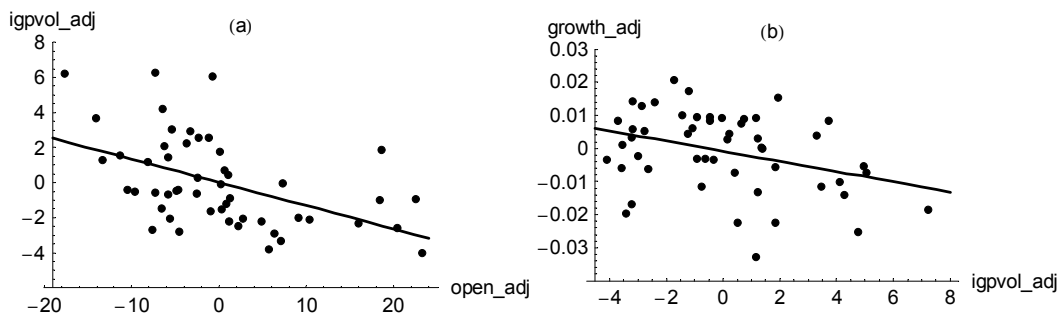


Figure 1: The link between openness, intermediate goods price volatility, and economic growth.

Note: Panel (a) corresponds to estimation (1) shown in Section 7, Table 1 (lower part), where *open\_adj* is the residual from regressing *open* on all other RHS variables. The variable *igpvol\_adj* is the residual from regressing *igpvol* on all RHS variables except *open*. Panel (b) corresponds to estimation (1) shown in Table 1 (upper part), where *igpvol\_adj* is the residual from regressing *igpvol* on all other RHS variables. The variable *growth\_adj* is the residual from regressing *growth* on all RHS variables except *igpvol*.

<sup>4</sup>This is analogous to roundaboutness in production in standard (neoclassical) growth models, in which the productivity of labor increases due to capital accumulation.

<sup>5</sup>The definition of the respective measures for openness, intermediate goods price volatility, and economic growth are explained in Section 7.

Moreover, there is also empirical evidence for a negative partial correlation between the volatility of intermediate goods prices and economic growth, which is illustrated by the scatter plot in Figure 1 (b). The respective points show combinations of the (adjusted) standard deviation of intermediate goods prices ( $igpvol\_adj$ ) and the (adjusted) growth rates ( $growth\_adj$ ), as resulting from a basic growth regression controlling for standard growth correlates. The estimated coefficient, as illustrated in Figure 1 (b), is negative and statistically significant across different empirical specifications. This indicates that a reduction in the volatility of intermediate goods prices tends to speed up growth. Taken together, there seems to be empirical support for the channel of more openness reducing the volatility of intermediate goods prices, which in turn fosters economic growth.

We set up a model of a stylized economy, which allows us to investigate the nexus between market integration, trade in intermediate goods, and economic growth. The model comprises two sectors: a final output sector and an intermediate goods sector. Production in the intermediate goods sector is subject to random shocks. Moreover, there are two types of firms in the final output sector: the representative traditional firm employs capital only, whereas the representative modern firm combines intermediate goods together with capital, i.e. produces intermediate goods intensive.

The basic idea underlying this paper is fairly simple and can be sketched as follows: Provided that productivity shocks are not perfectly correlated across countries, market integration leads to a reduction in the volatility of intermediate goods prices.<sup>6</sup> As a result, the volatility of the rate of return (ROR) of capital allocated to modern firms decreases. The induced portfolio decision of households then leads to a reallocation of capital from traditional firms to modern firms. Despite the presence of a precautionary saving channel (according to which, using empirically plausible calibrations, a reduction in volatility depresses growth), the growth rate can be shown to unambiguously increase due to the reallocation of capital.

Turning to the related literature, the paper is probably closest to Obstfeld (1994), who studies the consequences of international financial market integration on risk taking and long run growth. There are, however, a number of important differences:<sup>7</sup> First, the paper at hand investigates the consequences of goods market integration and is hence devoted to the real side of the economy. Second, we set up a general equilibrium model where the ROR differential, and to some extent the riskiness of investments, arises endogenously. This is due to specialization as well as an additional

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<sup>6</sup>This assumption is critical. However, it is also fairly reasonable and empirically valid.

<sup>7</sup>We will return to a comparison between the real channel, developed in this paper, and the financial channel described in Obstfeld (1994) in Section 6 below.

roundaboutness in production, both made possible by the use of intermediate goods. In contrast, Obstfeld (1994) assumes that there are two linear investment projects, one safe low-yield and one risky high-yield project.<sup>8</sup>

We do not explicitly model the causes of trade in intermediate goods. Since the economies under consideration possess the same constant returns to scale technologies and the same factor endowments, there is no reason for international specialization.<sup>9</sup> The possible explanations behind trade in intermediate goods have recently been investigated by Kleinert (2003).

The present paper contributes also to the literature on volatility and growth. Ramey and Ramey (1995) have shown that volatility and growth are negatively correlated. In the wake of this influential paper, a strand of empirical literature has developed which investigates the volatility growth nexus more deeply. For instance, Kose et al. (2004) argue that the volatility growth relationship might be affected by vigorous development trends such as globalization. In this context, the authors state that there is little theoretical evidence in this respect: "*... neither theoretical studies nor empirical ones have rigorously examined the effects of increased trade and financial linkages on the growth-volatility relationship*" (Kose et al., 2004, p. 6). The paper at hand contributes to this strand of literature by showing that goods market integration unfolds a tendency to reduce volatility and speed up growth. Moreover, it is shown that the model is consistent with the basic finding of Ramey and Ramey.

The paper is structured as follows: Section 2 introduces the basic deterministic model. Section 3 is devoted to the consequences of market integration for intermediate goods prices. In Section 4, the basic setup is extended to allow for productivity shocks in intermediate goods production. Section 5 discusses the main implications of market integration with respect to intermediate goods price volatility and economic growth. Section 6 treats the similarities and differences of the basic channel derived in this paper and the international portfolio diversification mechanism. Section 7 provides empirical results on the channel under study based on panel data for 9 OECD countries. Finally, Section 8 summarizes and concludes. All derivations and proofs have been relegated to an appendix (Section 9).

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<sup>8</sup>Devereux and Smith (1994) employ a multinational endogenous growth framework to show that international risk sharing can lower both growth and welfare. This is, of course, due to the basic second-best character of their model.

<sup>9</sup>However, trade between residents of the economies under study does arise in the integration equilibrium.

## 2 The deterministic economy

### 2.1 Firms

In the final output sector, there are two types of firms. Output of the representative traditional firm is denoted as  $y_T$ , while output of the representative modern firm is labelled  $y_M$ . The production technologies of the two types of firms read as follows:

$$y_T = A(1 - \theta)k \quad (1)$$

$$y_M = A(\theta k)^\alpha x^{1-\alpha}, \quad (2)$$

where  $A > 0$  denotes a constant technology parameter,  $0 \leq \theta \leq 1$  is the share of capital allocated to modern firms (implying that the share  $1 - \theta$  is allocated to traditional firms),  $0 < \alpha < 1$  a constant technology parameter and  $x$  is a (homogenous) intermediate input. Both type of firms produce under constant returns to scale. The traditional firm employs capital only, whereas the modern firm uses an intermediate input in addition to capital. This additional roundaboutness in production may lead to a more efficient production process, as will be shown below.

There is a large number of intermediate goods producers. The typical intermediate goods producer can convert  $\eta > 0$  units of  $y := y_M + y_T$  into one unit of  $x$ . Final output  $y$  serves as numeraire, its price is set equal to unity. Hence, the supply price of  $x$  is given by  $p_x^S = \eta$ . From equilibrium in the  $x$ -market (i.e.  $p_x^S = p_x^D$ ) and the demand price  $p_x^D = (1 - \alpha)A(\theta k)^\alpha x^{-\alpha}$ , the equilibrium amount of  $x$  can be readily derived to read as follows:

$$x = \left( \frac{A(1 - \alpha)}{\eta} \right)^{\frac{1}{\alpha}} \theta k. \quad (3)$$

From (2) and (3) one obtains the *reduced form production function* for  $y_M$ :<sup>10</sup>

$$y_M = A^{\frac{1}{\alpha}} \left( \frac{\eta}{1 - \alpha} \right)^{\frac{\alpha-1}{\alpha}} \theta k. \quad (4)$$

Provided that  $A^{\frac{1}{\alpha}} \left( \frac{\eta}{1 - \alpha} \right)^{\frac{\alpha-1}{\alpha}} > A$ , roundabout production is efficient. It will turn out below that, in this case, the representative household sets  $\theta$  equal to unity. In contrast, for  $A^{\frac{1}{\alpha}} \left( \frac{\eta}{1 - \alpha} \right)^{\frac{\alpha-1}{\alpha}} < A$ , roundabout production is inefficient and optimal  $\theta$  is set equal to zero. It is clear that in this deterministic economy only one type of production process is active.<sup>11</sup>

<sup>10</sup>This production function is structurally similar to the one employed in Barro (1990).

<sup>11</sup>This is due to the simplifying assumption according to which  $y_T$  and  $y_M$  are perfect substitutes in consumption, as explained in the next section.

For future use it is instructive to consider the *indirect production function*:<sup>12</sup>

$$y_M = A^{1/\alpha}(1 - \alpha)^{\frac{1-\alpha}{\alpha}} p_x^{\frac{\alpha-1}{\alpha}} \theta k. \quad (5)$$

This formulation shows that changes in the price of intermediate goods affect the productivity of capital (employed by modern firms) in a similar way to (multiplicative) technology shocks. The economic intuition behind this implication is straightforward: For instance, a drop in  $p_x$  increases the final output producer's demand for  $x$ . Since, in equilibrium, physical capital is combined with a larger amount of  $x$ , the productivity of capital increases.

## 2.2 Households

As usual, the representative household is assumed to maximize the present value of utility given by:

$$U = \int_0^{\infty} u(c) e^{-\rho t} dt, \quad (6)$$

where  $\rho > 0$  denotes the time preference rate and  $t$  the time index. The instantaneous utility function reads as follows:

$$u(c) = \frac{c^{1-\sigma} - 1}{1 - \sigma}, \quad (7)$$

where  $\sigma > 0$ . Output of the traditional firm ( $y_T$ ) and output of the modern firm ( $y_M$ ) are perfect substitutes in consumption  $c$ , i.e.  $c = y_T^c + y_M^c$  with  $y_T^c$  and  $y_M^c$  denoting the amounts of  $y_T$  and  $y_M$  consumed, respectively.<sup>13</sup> Hence, the relative price of  $y_T$  in terms of  $y_M$  is fixed to unity. The economy's resource constraint can be expressed as  $y_T + y_M = c + \eta x + \dot{k}$ , where  $\dot{k} := dk/dt$ .

The representative household can, in principle, hold assets in one of three forms: (i) ownership claims on traditional firms; (ii) ownership claims on modern firms; or (iii) consumption loans. Both ownership claims and loans are perfect substitutes as stores of value and hence must pay the same ROR. A household's net asset holding is denoted by  $a$ .<sup>14</sup> Due to perfect competition in the capital market and the production technologies (1) and (2), ownership claims on traditional firms pay a ROR of  $r_T = A$ , while ownership claims on modern firms pay a ROR of  $r_M = A^{\frac{1}{\alpha}} \left(\frac{\eta}{1-\alpha}\right)^{\frac{\alpha-1}{\alpha}}$ . The flow budget constraint for the household is:

$$\dot{a} = r_T(1 - \theta)a + r_M\theta a - c,$$

<sup>12</sup>Solve the first order condition  $p_x^D = (1 - \alpha)A(\theta k)^\alpha x^{-\alpha}$  for  $x$  and substitute into (2).

<sup>13</sup>This assumption is not critical for the results derived below but greatly simplifies the analysis.

<sup>14</sup>Since households are identical there will be no loans in equilibrium and thus  $k = a$ .



where  $\dot{a} := da/dt$ . The solution to the above-sketched optimization problem leads to the familiar Keynes-Ramsey rule of optimal consumption:

$$\frac{\dot{c}}{c} = \frac{r - \rho}{\sigma},$$

where  $r = r_T = A$  for  $A^{\frac{1}{\alpha}} \left(\frac{\eta}{1-\alpha}\right)^{\frac{\alpha-1}{\alpha}} < A$  and  $r = r_M = A^{\frac{1}{\alpha}} \left(\frac{\eta}{1-\alpha}\right)^{\frac{\alpha-1}{\alpha}}$  for  $A^{\frac{1}{\alpha}} \left(\frac{\eta}{1-\alpha}\right)^{\frac{\alpha-1}{\alpha}} > A$ .<sup>15</sup>

### 3 Market integration

Consider two economies which are perfectly identical except for the input coefficients in intermediate goods production  $\eta$ . The equilibrium price of intermediate goods in the integrated economy  $p_x^i$  is given by (we assume that the conditions for interior solutions hold):

$$p_x^i = \min(\eta_1, \eta_2), \quad (8)$$

where  $\eta_1$  and  $\eta_2$  denote the input coefficients in intermediate goods production in country 1 and 2, respectively. Provided that  $\eta_1 = \eta_2$ , the world market price is identical to the autarky price. In this case, the world economy replicates the economies under autarky. Integrating two perfectly identical economies has no consequences within this deterministic setup. This changes provided that (i) one allows the technology parameters  $\eta_1$  and  $\eta_2$  to become stochastic and (ii) one assumes (realistically) that the national shocks are not perfectly correlated.<sup>16</sup>

Inserting the intermediate goods price under integration (8) into the indirect production function (5) gives the *reduced form production function under integration*:

$$y_M = A^{1/\alpha} (1 - \alpha)^{\frac{1-\alpha}{\alpha}} [\min(\eta_1, \eta_2)]^{\frac{\alpha-1}{\alpha}} \theta k. \quad (9)$$

This formulation immediately points to the fact that the volatility of the marginal product of capital allocated to the modern sector decreases in response to economic integration whenever the volatility of the expression  $[\min(\eta_1, \eta_2)]^{\frac{\alpha-1}{\alpha}}$  is smaller than the volatility of  $\eta^{\frac{\alpha-1}{\alpha}}$ .

### 4 The stochastic economy

In this section we introduce uncertainty into the model set up above. As the analysis proceeds we distinguish between autarky and integration to reveal the consequences

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<sup>15</sup>In equilibrium, only one type of ownership claims is actually held by private households. The decision on  $\theta$  is trivial in the deterministic setup.

<sup>16</sup>The two shocks will be assumed to follow the same probability distribution but they represent independent realizations (idiosyncratic shocks).

of market integration in the stochastic environment.

#### 4.1 The return on capital employed by modern firms

It is now assumed that the production of intermediate inputs is subject to random shocks. Specifically, the input coefficient  $\eta$  fluctuates randomly in a stationary fashion and is described by the following simple probability distribution:<sup>17</sup>

$$\eta = \begin{cases} \bar{\eta} + \varepsilon & \text{with } P(\bar{\eta} + \varepsilon) = 0.5 \\ \bar{\eta} - \varepsilon & \text{with } P(\bar{\eta} - \varepsilon) = 0.5, \end{cases} \quad (10)$$

where  $\varepsilon > 0$ . The expected value of  $\eta$  is  $E(\eta) = \bar{\eta}$ .<sup>18</sup>

Considering the reduced form production functions under autarky (4) and integration (9) shows that the ROR per period of time  $dt$  of capital allocated to modern firms under autarky ( $r_M^a$ ) and integration ( $r_M^i$ ) is:

$$r_M^a = b\eta^{\frac{\alpha-1}{\alpha}} \quad (11)$$

$$r_M^i = b[\min(\eta_1\eta_2)]^{\frac{\alpha-1}{\alpha}}, \quad (12)$$

where  $b := A^{1/\alpha}(1-\alpha)^{\frac{1-\alpha}{\alpha}}$ . Using  $V(u)$  to denote the variance of some variable  $u$ , the variance of  $r_M^a$  is  $b^2V(\eta^{\frac{\alpha-1}{\alpha}})$ , while the variance of  $r_M^i$  is  $b^2V[(\min(\eta_1\eta_2))^{\frac{\alpha-1}{\alpha}}]$ . The relation between the volatility of the ROR of capital allocated to modern firms under autarky and integration is described by

**Proposition 1:**

*Provided that two identical economies with a production structure as described in Section 2.1 and idiosyncratic shocks in intermediate goods production according to (10) join a goods market integration, the variance of the ROR of capital employed by modern firms under integration is given by  $V(r_M^i) = 0.75V(r_M^a)$ .*

**Proof:** See the appendix.

It should be observed that the reduction in the volatility of the ROR is due to goods market integration and not, as in Obstfeld (1994), the result of portfolio diversification in an integrated financial market.

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<sup>17</sup>This is similar to Bertola (1994, p. 219), who sets up a continuous time growth model with intermediate goods assuming that stochastic productivity of the intermediate goods producer follows a binary scheme.

<sup>18</sup>Moreover, we assume that roundabout production is always efficient, i.e.  $A^{\frac{1}{\alpha}} \left( \frac{\eta}{1-\alpha} \right)^{\frac{\alpha-1}{\alpha}} > A$  holds. Otherwise, the solution to the stochastic optimization problem would be trivial with  $\theta = 0$ .

The ROR of capital in modern firms is now decomposed into a deterministic and a stochastic component.<sup>19</sup> On this occasion, we distinguish between autarky and integration employing the result that  $V(r_M^i) = 0.75V(r_M^a)$ . In the appendix it is shown that the ROR (per period  $dt$ ) can be expressed as follows:<sup>20</sup>

$$r_M^a = \bar{r}_M dt + \lambda(dn_1 - dn_2) \quad (13)$$

$$r_M^i = \bar{r}_M dt + \sqrt{0.75}\lambda(dn_1 - dn_2), \quad (14)$$

where  $\bar{r}_M := bE(\eta^{\frac{\alpha-1}{\alpha}})$  and  $\lambda > 0$ . Several aspects should be noted: First, to simplify matters, we hold the expected ROR in the modern sector  $\bar{r}_M$  fixed. The model under study implies that the expected ROR indeed increases in response to market integration. Taking this effect into account would even strengthen the results derived below.<sup>21</sup> Second, the stochastic component is represented by a composite and symmetric Poisson increment  $\lambda(dn_1 - dn_2)$ , where  $dn_1 = 1$  with probability  $\gamma dt$  and  $dn_1 = 0$  with  $(1 - \gamma)dt$  and, analogously,  $dn_2 = 1$  with  $\gamma dt$  and  $dn_2 = 0$  with  $(1 - \gamma)dt$ .<sup>22</sup> This type of uncertainty is compatible with the binary shock scheme given by (10). It should be noted that the choice of the type of uncertainty, i.e. Wiener versus Poisson uncertainty, is largely a matter of taste since the results are qualitatively identical (Steger, 2005). Third, the representation of the ROR shown in (13) is equivalent to (11) in the sense that both expected value and variance are identical. The first requirement is satisfied by construction (symmetry). The second requirement can be easily satisfied by choosing the parameters  $\lambda$  and  $\gamma$  such that  $V[\lambda(dn_1 - dn_2)] = b^2V(\eta^{\frac{\alpha-1}{\alpha}})$ .<sup>23</sup>

Finally, we assume the following timing of events:  $x$ -producers decide on the supply of  $x$  and  $y_M$ -producers decide on the demand for  $x$  after the shocks have materialized. Hence, both types of firm solve a sequence of deterministic problems. However, the equilibrium amount of  $x$  is stochastic and, according to (4), the productivity of capital employed by modern firms is also stochastic. Moreover, we assume that households decide on their portfolio allocation before the productivity shock occurs. The ROR of ownership claims on modern firms is stochastic and portfolio

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<sup>19</sup>This enables the application of standard methods for stochastic dynamic optimization under Poisson uncertainty. For dynamic optimization under Poisson uncertainty see Wälde (1999) and Sennewald and Wälde (2005).

<sup>20</sup>This formulation of the stochastic ROR is standard in the literature on stochastic growth models; for instance, see Eaton [1981, equations (10) and (11)].

<sup>21</sup>Another reason for ignoring the consequences on the expected ROR lies in the fact that this effect becomes very small when the supply curve for intermediate goods is upward sloping.

<sup>22</sup>In addition, note that  $E[\lambda(dn_1 - dn_2)] = 0$  and  $V[\lambda(dn_1 - dn_2)] = 2\lambda^2\gamma dt - 2\lambda^2\gamma^2 dt^2$ .

<sup>23</sup>A similar statement applies to (14) and (12). In this case one must, however, take the qualification that the expected ROR in the modern sector  $\bar{r}_M$  is held fixed into account.

decisions are made under uncertainty.

## 4.2 Households

The intertemporal stochastic decision problem of the representative household is described and subsequently its solution is discussed. Again, we distinguish between the case of autarky and integration.

Considering the ROR of capital allocated to modern firms [(13) and (14)], the flow budget constraint of the representative household is described by a stochastic differential equation in net assets  $a$ :

$$da = [\bar{r}_M \theta a + r_T(1 - \theta)a - c]dt + \theta a \phi \lambda (dn_1 - dn_2), \quad (15)$$

where  $\bar{r}_M$ ,  $r_T$ ,  $dn_1$ , and  $dn_2$  are defined as above. The first term on the RHS shows the continuous evolution of  $a$ , which is given by the difference between capital income (an average ROR times the stock of net assets) minus consumption. The second term on the right hand side gives the discontinuous jump in net assets due to stochastic increments in the ROR, as described above.

Recalling (13) and (14) indicates that for  $\phi = 1$  equation (15) gives the flow budget constraint of the representative household under autarky. On the other hand, for  $\phi = \sqrt{0.75}$  equation (15) describes the flow budget constraint under integration.<sup>24</sup>

The general formulation of the flow budget constraint in (15) has the advantage that the intertemporal problem needs to be solved only once. The implications of economic integration for the household's portfolio decisions, and the consequences for intersectoral capital allocation, can then be found by comparative static analysis with respect to  $\phi$ . This simplification is made possible by the fact that the household's decisions under uncertainty are predominantly determined by the expected value and the variance of the ROR.

As usual, the household is assumed to maximize the expected present value of utility. The underlying dynamic problem comprises one state variable  $a$  and two control variables, namely  $c$  and  $\theta$ :

$$\begin{aligned} \max_{\{c, \theta\}} E_0 \int_0^{\infty} u(c) e^{-\rho t} dt \\ \text{s.t. (15); } a(0) = a_0 > 0; \quad 0 \leq c \leq y; \quad 0 \leq \theta \leq 1, \end{aligned} \quad (16)$$

where  $E_0$  denotes the expectation operator, conditional on information at  $t = 0$ .

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<sup>24</sup>In a more general model with asymmetric economies and a large number of economies,  $\phi$  could be considered as continuous variable on  $(0, 1]$ .

## 5 Main implications

The solution to the dynamic problem (16) determines the asset allocation share  $\theta$  as well as the consumption wealth ratio  $\Psi := c/a$ . Both  $\theta$  and  $\Psi$  then pin down the expected growth rate of consumption  $E(dc)/(cdt)$ .<sup>25</sup>

**Asset allocation share  $\theta$ .** The optimal share of assets invested in ownership claims issued by modern firms  $\theta$  is implicitly determined by the following first order condition for  $\theta$ :

$$\bar{r}_M - r_T = \phi\lambda\gamma[(1 - \phi\lambda\theta)^{-\sigma} - (1 + \phi\lambda\theta)^{-\sigma}]. \quad (17)$$

The left hand side of (17) gives the differential between the (expected) ROR of capital allocated to modern firms and the ROR of capital allocated to traditional firms. The right hand side can be expressed as  $\gamma\phi\lambda\frac{u'(\tilde{c})}{u'(c)} - \gamma\phi\lambda\frac{u'(c)}{u'(\tilde{c})} > 0$ , where  $\tilde{c}$  denotes the level of consumption after a downward jump in  $a$  and  $\bar{c}$  denotes consumption after an upward jump in  $a$ , respectively.<sup>26</sup> This term gives the difference between the expected proportional change in marginal utility in response to a downward jump in  $a$ , i.e.  $\gamma\phi\lambda\frac{u'(\tilde{c})}{u'(c)}$ , and the expected proportional change in marginal utility in response to an upward jump in  $a$ , i.e.  $\gamma\phi\lambda\frac{u'(c)}{u'(\bar{c})}$ .<sup>27</sup> Since the utility function is concave, there is a desire for consumption smoothing and hence the expression on the RHS of (17) can be considered as a measure of the costs of (discontinuous) changes in  $u'(c)$ . By choosing  $\theta$  the household can control this expression. The first order condition (17) thus says that the household chooses  $\theta$  such that the marginal benefit of increasing  $\theta$ , given by the LHS of (17), equals the marginal cost of increasing  $\theta$ , given by the RHS of (17).

By applying the implicit function theorem to (17), one can determine the consequences of market integration with respect to the optimal portfolio choice, which is summarized by

**Proposition 2:**

*Market integration (which is captured by a drop in  $\phi$  from 1 to  $\sqrt{0.75}$ ) leads to an increase in the share of assets invested in modern firms, i.e.  $\frac{\partial\theta}{\partial\phi} < 0$ . As a result, the average ROR earned by the representative household  $r := r_T(1 - \theta) + \bar{r}_M\theta$  increases.*

**Proof:** See the appendix.

<sup>25</sup>Nearly all derivations have been relegated to the appendix.

<sup>26</sup>Since  $\Psi = c/a$  will turn out to be constant in equilibrium any jump in  $a$ , due to a shock in the ROR according to (15), induces an equi-proportionate jump in  $c$ .

<sup>27</sup>For instance,  $\gamma$  is the probability of a downward jump,  $\phi\lambda$  gives the proportional rate of change in  $a$ , equal to the rate of change of  $c$ , and  $\frac{u'(\tilde{c})}{u'(c)}$  is the proportional change in marginal utility.

The intuition behind this proposition is straightforward. Market integration leads to a reduction in the volatility of intermediate goods prices and in turn to a reduction in the volatility of the ROR of ownership claims on modern firms. Thus  $\frac{\partial \theta}{\partial \phi} < 0$  simply states that risk averse households invest more in risky assets in response to a declining riskiness.

We are now in the position to describe the consequences of market integration with respect to the household's portfolio decision. In an integrated economy the volatility of intermediate goods prices and hence the volatility of the ROR of the risky asset are smaller compared to the autarky case. This is captured by the parameter  $\phi$  in (17), which is  $\phi = 1$  under autarky and  $\phi = \sqrt{0.75}$  under integration. With a smaller volatility in the ROR, the costs of changes in marginal utility, as given by the RHS of (17), fall. As a result, the household increases  $\theta$  to reestablish the optimality condition (17).

Figure 2 illustrates this reasoning. The horizontal axis shows the asset allocation share  $\theta$ . The horizontal solid line gives  $\bar{r}_M - r_T$  (labeled LHS). The solid upward sloping curve (RHS - Autarky) shows the marginal costs of increasing  $\theta$ , valid under autarky. The optimal choice of  $\theta$  is determined by the intersection between these two curves. In response to market integration, the volatility of the ROR of the risky asset drops and, for fixed  $\theta$ , the marginal costs of increasing  $\theta$  decrease. This means that the upward sloping "marginal cost curve" is rotated downwards at the origin. The dashed upward sloping curve (RHS - Integration) shows the marginal costs under integration. Accordingly, the representative household increases  $\theta$  until marginal benefits equal marginal costs.

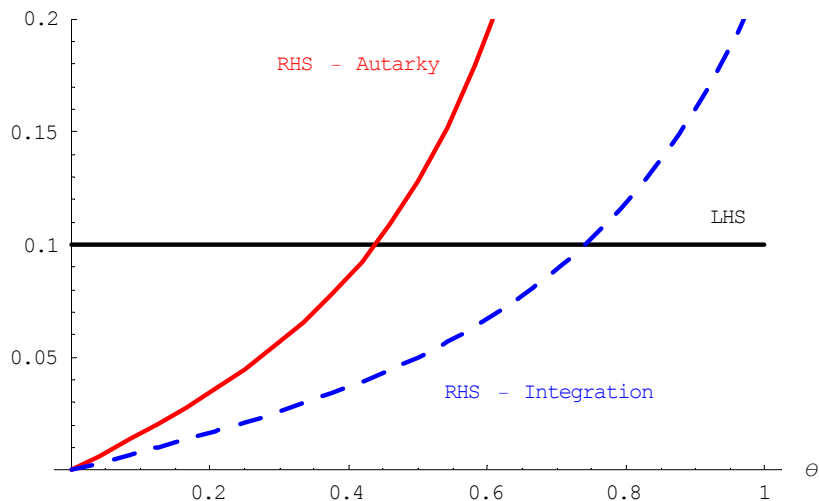


Figure 2: Market integration and optimal asset allocation; LHS and RHS refer to equation (17)

This portfolio shift is mirrored by a reallocation of physical capital from traditional firms to modern firms.<sup>28</sup>

**Consumption wealth ratio  $\Psi$ .** The optimal consumption asset ratio  $\Psi := c/a$  turns out to read as follows:

$$\Psi = \frac{(\sigma - 1)r + \rho}{\sigma} + \frac{\gamma}{\sigma}[2 - (1 + \phi\lambda\theta)^{1-\sigma} - (1 - \phi\lambda\theta)^{1-\sigma}], \quad (18)$$

where  $r := r_T(1 - \theta) + \bar{r}_M \theta$ . The question how  $\Psi$  varies with a change in  $\phi$  is all but trivial. An important benchmark case is  $\sigma = 1$  (logarithmic utility), which implies  $\Psi = \rho$ . The consumption wealth ratio is a constant and not affected by a change in the volatility of the risky asset.<sup>29</sup> The more general case  $\sigma \neq 1$  is described by

**Proposition 3:**

(i) *Provided that  $\sigma > 1$ , the optimal consumption wealth ratio increases in response to market integration (a drop in  $\phi$  from 1 to  $\sqrt{0.75}$ ), i.e.  $\frac{\partial\Psi}{\partial\phi} < 0$ .*

(ii) *For  $\sigma < 1$ , the optimal consumption wealth ratio decreases in response to market integration (a drop in  $\phi$  from 1 to  $\sqrt{0.75}$ ), i.e.  $\frac{\partial\Psi}{\partial\phi} > 0$ .*

**Proof:** *See the appendix.*

The economic intuition is best described by employing the concept of certainty equivalent ROR (Weil, 1990). A reduction in  $\phi$ , equivalent to a reduction in the volatility of the ROR of capital employed by modern firms, increases the certainty equivalent ROR of capital allocated to modern firms. This unfolds an intertemporal substitution effect, i.e. less contemporaneous consumption, and an intertemporal income effect, i.e. more contemporaneous consumption. For  $\sigma > 1$ , the income effect dominates the substitution effect such that  $\Psi$  rises. This is the well known precautionary saving mechanism. It is important to notice that the empirically relevant case is  $\sigma > 1$ . Hence, market integration should increase  $\Psi$ , i.e. reduce the saving rate, and depress growth.

**Expected growth rate  $E(dc)/cdt$ .** The analysis conducted so far has revealed that (i) market integration increases  $\theta$  and thereby raises  $r$ ; this reallocation effect fosters growth. (ii) For  $\sigma > 1$  (which is empirically relevant) market integration increases  $\Psi$ , which depresses growth. It is, therefore, interesting to see whether

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<sup>28</sup>In the model this reallocation occurs instantaneously. In the real world this process is distributed over time due to capital reallocation costs.

<sup>29</sup>This is, of course, due to the fact that the intertemporal substitution and income effect exactly cancel.

any clear-cut proposition can be made with respect to the consequences of market integration for the expected growth rate.

The expected growth rate of consumption (per period of time) can be shown to read as follows:

$$\frac{E(dc)}{c dt} = \frac{r - \rho}{\sigma} - \frac{\gamma}{\sigma} [2 - (1 + \phi\lambda\theta)^{1-\sigma} - (1 - \phi\lambda\theta)^{1-\sigma}]. \quad (19)$$

Again, an interesting benchmark case is  $\sigma = 1$ , which implies  $E(dc)/c dt = r - \rho$ . On account of Proposition 2, market integration would unambiguously foster growth, due to reallocation of capital at constant  $\Psi$ . The remaining cases ( $\sigma \neq 1$ ) are described by

**Proposition 4:**

*The expected growth rate of consumption  $E(dc)/(c dt)$  unambiguously increases in response to market integration (a drop in  $\phi$  from 1 to  $\sqrt{0.75}$ ), i.e.  $\frac{\partial E(dc)/c dt}{\partial \phi} < 0$ .*

**Proof:** See the appendix.

This proposition simply states that, even in the case of  $\sigma > 1$ , the reallocation effect dominates the precautionary saving effect. As a consequence, market integration has been shown, in the model setup under study, to unambiguously foster growth.

## 6 Relation between real and financial channel

The model under study describes the following channel: Integration of (intermediate) goods market leads to (i) a drop in the volatility of intermediate goods prices; (ii) a reduction in the volatility of intermediate goods employed by modern firms; (iii) a fall in the volatility of the marginal product of physical capital allocated to modern firms; and (iv) a lower riskiness of the ROR of financial capital invested in modern firms. This channel is labeled the *real channel of risk reduction*.<sup>30</sup>

The preceding mechanism is reminiscent of the *international portfolio diversification mechanism* familiar from the literature on international macroeconomics (Obstfeld, 1994). Provided that the ROR of national investments are not perfectly correlated across countries, financial market integration enables an international portfolio diversification. The volatility of the ROR of an internationally diversified portfolio is smaller compared to the national portfolio. This reduction in volatility is welfare enhancing. Moreover, using a partial equilibrium framework, Obstfeld (1994) has

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<sup>30</sup>With risk averse households, this effect itself is welfare improving. Moreover, there is a reallocation of capital from traditional firms (less risky, lower yield) to modern firms (more risky, higher yield). This second effect boosts growth.



shown that financial market integration leads to a reallocation of capital in favour of the risky, high-yield investment, thereby fostering growth.

The two mechanisms share some similarities, but are also different in important respects. First, and most obvious, the real channel of risk reduction is related to goods market integration, whereas the international portfolio diversification mechanism is related to financial market integration. Second, in both cases international integration leads to a reduction in the volatility of the ROR of the portfolio held by the representative household. However, the volatility of the ROR of the risky national investment(s) is not affected by financial market integration and international portfolio diversification. In contrast, the real channel of risk reduction implies that the volatility of the ROR of the risky national investment itself drops in response to international goods market integration. Third, there is also an important difference concerning the action taken by the representative household: in the case of international portfolio diversification, the household reshuffles its portfolio by actively buying foreign assets. The real channel requires less conscious actions to be taken by economic agents. All that is needed here is the functioning of an integrated intermediate goods market in the sense of "one good one price".

At this stage, the question arises whether the real channel of risk reduction and the portfolio diversification channel are substitutes or complements. To clarify this aspect, consider the following situation: Two economies, characterized by the structure as described above, integrate their financial markets. Without further restrictions, this leads to international portfolio diversification à la Obstfeld. Next, the economies under consideration integrate their (intermediate) goods market. Does this mean that the real channel of risk reduction becomes obsolete? The answer is no. The mechanism works exactly in the same way as described above. In response to intermediate goods market integration, the volatility (i) of intermediate goods prices, (ii) of the amount of intermediate goods employed by modern firms, (iii) of the marginal product of physical capital and (iv) of the ROR of financial capital allocated to modern firms drops in the same way as under financial autarky.

## **7 Empirical evidence for OECD countries**

The model set up above implies that the volatility of intermediate goods prices has a negative impact on the growth rate of output. Moreover, the price volatility itself is negatively affected by the trade openness of an economy. These two empirical hypotheses are now tested econometrically. We use five-year average data from 1960 to 2000 of the 9 OECD countries providing adequate statistics for intermediate goods

prices.<sup>31</sup> In this sample, the number of cross-sectional units is small so that the standard errors of a GLS-random effects estimator become unreliable. Consequently, we first adopt the estimation procedure of panel corrected standard errors (PCSE) which is designed exactly for this kind of data. In a next step, the PCSE results are compared with a fixed effects (FE) model. To test for the relationship between the two equations implied by the model, we present two variants. In the single equation estimation for growth we introduce an interaction term to capture the link between price volatility and openness. We then proceed with simultaneous-equation estimations. By adopting the three-stage least squares (3SLS) procedure, consistency and efficiency are achieved by instrumentation and appropriate weighting, respectively. Finally, the equations are alternatively tested using the seemingly unrelated regression (SUR) technique.

The endogenous variables are real per capita growth of GDP *growth* and our measure of the price volatility *igppvol* which is the average standard deviation of monthly intermediate goods prices. The macroeconomic data are taken from the Penn World Table, version 6.1, see Heston et al. (2002), and from Barro and Lee (1994, 2000), while the price series are provided by OECD (2005), see the appendix for a detailed description of the underlying data set. As additional explanatory variables in the growth regressions we use the variables which have proven to be robust in recent empirical growth literature, specifically (the logarithm of) initial GDP per capita *logingdp*, initial human capital *inhcap*, the average investment share *invshare*, and average population growth *popgrowth*. In the price volatility regressions, we use - besides the openness measure *open* - a variable for the (average) standard deviation of monthly oil prices *opvol*. Oil is a primary input and not an intermediate good with different price volatilities in the different countries as treated in the above model. However, it has a high volatility which also affects intermediate goods prices; the correlation between the two price volatilities is 0.39. As openness is also affected by geographic variables we introduce the variables *area* and *dist* for the land area and the average distance to the main trade partners, respectively, as additional exogenous variables or as instruments in the case of the 3SLS estimations. Regarding the time specific effects, different dummies for time periods are introduced. Because the dummy variable for the period 1990-95 is always significant in the growth regressions, we include it in all estimations; the German reunification and its impact on the EU and, to a lesser extent, the first Irak war are the reasons why the growth process

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<sup>31</sup>The sample covers Belgium, Denmark, Spain, Finland, France, UK, Germany, the Netherlands, and the USA. As certain countries report shorter price series the panel is unbalanced. For three countries the definition of intermediate goods deviates marginally from the others (energy, food), which has been corrected so that the prices become comparable.

appears to be specific during that time period.

Table 1 reports the results of the different regressions. In columns (1) to (5), the system is estimated separately for the growth equation, with the results provided in the upper half of the table, and the price volatility relation, with the results given below. (6) and (7) represent simultaneous-equation estimations, so that the whole column belongs to the same estimation.

Let us first discuss (1) to (5). In the growth estimations, we observe that the variable of main interest *igppvol* appears negative and significant throughout the different specifications. The first equation (1) uses the initial conditions in addition to the price volatility as explanatory variables. The initial GDP per capita has the negative sign which is well-known from literature showing (conditional)  $\beta$ -convergence in income levels. In (2), the investment share and the population growth have no significant impact on growth, which is tolerable for the case of OECD countries with little variation in these respects. In equation (3) we have included all the period dummies, except *dum95-2000* to avoid perfect collinearity, without reporting their specific impact to save space. Only *dum80-85* is significant besides *dum90-95*. It turns out that the impact of intermediate goods prices remains robust and initial human capital *inhcap* becomes significant at the 10% level. To compare the PCSE procedure with a FE model, results of the specification in (1) obtained by FE are reported in equation (4), which exhibits a robust impact of *igppvol* with a somewhat weaker effect of the other exogenous variables. The impact of trade is first introduced in equation (5), with the interaction term *open\*igppvol*, which multiplies openness and price volatility. The negative and significant interaction term expresses that the more open the economy is, the larger becomes the negative impact of intermediate goods price volatility on growth, which is in accordance with our model.

In the single equation estimations (1) to (5) of the price volatility, we see that the openness variable *open* has a highly significant negative impact on intermediates price volatility *igppvol*, once the variation of oil prices is controlled for. This holds true for all specifications. Country-specific effects of price adjustments, which are e.g. determined by market forms, institutions and macroeconomic stability, are captured by dummy variables for all countries (except the US to avoid perfect collinearity); these results are not included in the table. The volatility of oil prices *opvol* has a positive impact on the intermediates price variation, which is significant. The estimated coefficient for land *area* has a positive sign whereas the distance to trade partners *dist* has a negative impact on price volatility as expected. In (3) below, the additional time dummies do not change the result just as the FE estimator does not alter the outcome, it is in fact similar to using country dummy variables.

Table 1: Estimation results (different estimation methods)

Endogenous variables: per capita growth (growth) and intermed. goods price volatility (igpvol)

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	PCSE	PCSE	PCSE, dum	FE	PCSE	3SLS	SUR
growth							
const	0.16** (0.07)	0.16** (0.07)	0.29* (0.16)	0.13 (0.13)	0.19*** (0.07)	0.15* (0.08)	0.15* (0.08)
igpvol	- 0.153*** (0.056)	- 0.151** (0.060)	- 0.112** (0.054)	- 0.154** (0.065)		- 0.150** (0.060)	- 0.127** (0.053)
open*igpvol					- 0.0022** (0.0009)		
logingdp	- 0.033* (0.019)	- 0.034* (0.019)	- 0.068* (0.040)	- 0.025 (0.037)	- 0.044*** (0.019)	- 0.032 (0.021)	- 0.033 (0.021)
inhcap	0.173 (0.137)	0.186 (0.142)	0.317* (0.175)	0.069 (0.427)	0.246* (0.140)	0.167 (0.141)	0.178 (0.140)
invshare		0.012 (0.061)					
popgrowth		0.032 (0.23)					
igpvol							
const	1.42 (1.07)	46.0** (21.7)	21.60*** (6.27)	6.45*** (1.81)		3.75** (1.58)	3.69** (1.58)
open	- 0.132** (0.055)	- 0.132** (0.055)	- 0.115*** (0.040)	- 0.132*** (0.037)		- 0.131*** (0.033)	- 0.130*** (0.033)
opvol	1.09*** (0.34)	1.09*** (0.34)	1.13*** (0.24)	1.09*** (0.28)		1.13*** (0.24)	1.13*** (0.24)
area		0.008* (0.004)	0.001*** (0.0004)				
dist		- 0.018** (0.009)	- 0.005*** (0.001)				
# of obs.	51	51	51	51	51	51	51
$R^2$ growth	0.45	0.45	0.57	0.44	0.43	0.45	0.45
$R^2$ igpvol	0.44	0.45	0.54	0.36		0.42	0.45
$\chi^2$ growth	46.30	48.11	985.46	-	37.66	0.45	42.2
$\chi^2$ igpvol	222.8	222.8	344.35	-		42.2	42.2

Note: Standard errors in parentheses; \* significant at the 10 % level; \*\* significant at the 5 % level; \*\*\* significant at the 1 % level.

In (6) we use the three-stage least square procedure to estimate the two relationships simultaneously. It is most interesting to see that the results do not deviate much from the outcome in columns (1) to (5). In particular, the impact of price volatility on growth and the effect of trade openness on the volatility are fully corroborated

by the simultaneous estimation. In (6), *area* and *dist* are used as exogenous instruments in the first stage, so that they do not appear in the table. The same is true for the time and country dummies. The introduction of several instruments is useful to reduce the scope for omitted variable bias. Finally, in (7) we use the alternative estimation technique of seemingly unrelated regression (SUR), which means running the simultaneous model without instrumenting for the endogenous variables. We find again a very similar result providing evidence for trade having a positive impact on growth via the volatility of intermediates goods prices. Thus we conclude that the theoretical model has identified an important channel in the globalization growth nexus.

## 8 Summary and conclusion

We have set up a dynamic general equilibrium growth model with productivity shocks in intermediate goods production to investigate a specific channel through which globalization affects economic growth. The model implies that the growth rate of output should be negatively correlated with the volatility of intermediate goods prices. This empirical hypothesis has been tested econometrically. The main results can be summarized as follows:

(1) Provided that productivity shocks in intermediate goods production are not perfectly correlated across countries, the long run growth rate increases in response to market integration. This is due to the fact that goods market integration reduces the volatility of intermediate goods prices which leads to a decrease in the volatility of the ROR of capital employed by those firms using intermediate goods intensively, which have been labelled modern firms. The induced portfolio adjustment of households then leads to a reallocation of capital from traditional firms to modern firms. Since modern firms are more productive, due to a higher degree of specialization and additional roundaboutness in production, economic growth increases.

(2) The result stated above is interesting since a reduction in the volatility of the (uncertain) ROR additionally unfolds a precautionary saving effect. Empirically plausible values for the coefficient of relative risk aversion (larger than 1) imply that this mechanism tends to reduce household savings, capital investment, and therefore growth. Nonetheless, it has been shown analytically that the reallocation mechanism always dominates the precautionary saving mechanism.

(3) The model is consistent with the finding of Ramey and Ramey (1995) according to which there is a negative relation between volatility and growth. Moreover, the model describes an important mechanism through which globalization affects the

volatility growth nexus. Goods market integration should strengthen this negative relationship. Such theoretical clarifications have recently been demanded by authors who have investigated this aspect empirically (Kose et al., 2004).

(4) Empirical investigations have shown that the growth rate of per capita income is indeed negatively correlated, after controlling for standard growth correlates, with the standard deviation of intermediate goods prices. This relationship is significant across different empirical specifications. Moreover, it has been shown empirically that the negative impact of intermediate goods price volatility on growth increases with the openness of an economy, which is perfectly in line with the logic of the model.

The paper points to a number of interesting issues for future research. For instance, there is an extensive literature investigating the welfare implications of financial market integration (e.g. Asdrubali et al., 1996; Gourinchas and Jeanne, 2003). Similarly, it would be interesting to assess the welfare consequences of the real channel of risk reduction in response to goods market integration. On this occasion, a sensible distinction could be made between perfect and imperfect competition in the intermediate goods sector.

## 9 Appendix

### 9.1 Data and descriptive statistics

This appendix gives the sources together with some descriptive statistics of the data set employed in Section 7.

Table 2: Data

Sources and test statistics				
Variable	Description	Source	Mean	St.Dev.
growth	real per capita GDP growth, constant prices, ref. 1996 (Laspeyres)	PWT 6.1	0.0267	0.0164
igpvol	St.dev. of monthly intermed. goods prices*	OECD MEI	3.934	3.001
logingdp	log of initial GDP per capita	PWT 6.1	4.162	0.149
inhcap	initial years of average schooling*	Barro/Lee (2000)	7.93	1.80
invshare	average investment share	PWT 6.1	25.06	4.21
popgrowth	population growth	PWT 6.1	0.0054	0.0037
open	exports+imports/GDP	PWT 6.1	47.86	28.84
area	land area	Barro/Lee (1994)	1264	2893
dist	average distance to trade partners	Barro/Lee (1994)	2904	1530

\*Data multiplied by 100 to increase readability of coefficients and standard errors reported in Table 1 (upper part).

### 9.2 Proofs

#### 9.2.1 Proposition 1: Volatility of ROR under autarky and integration

From the reduced form production function  $y_M = b\eta^{\frac{\alpha-1}{\alpha}}\theta k$  we get the ROR of capital in the modern sector under autarky  $r_M^a = b\eta^{\frac{\alpha-1}{\alpha}}$ , where  $\eta$  is described by:

$$\eta = \begin{cases} \bar{\eta} + \varepsilon & \text{with } P = 0.5 \\ \bar{\eta} - \varepsilon & \text{with } P = 0.5 \end{cases}$$

Turning to integration, the set of possible realizations, given the binary shock scheme in both countries (as displayed above), reads:

$$\begin{aligned} (\bar{\eta} + \varepsilon_1, \bar{\eta} + \varepsilon_2) & \text{ with } P = 0.25 \\ (\bar{\eta} + \varepsilon_1, \bar{\eta} - \varepsilon_2) & \text{ with } P = 0.25 \\ (\bar{\eta} - \varepsilon_1, \bar{\eta} + \varepsilon_2) & \text{ with } P = 0.25 \\ (\bar{\eta} - \varepsilon_1, \bar{\eta} - \varepsilon_2) & \text{ with } P = 0.25. \end{aligned}$$

where  $\varepsilon_1$  and  $\varepsilon_2$  denote shock realizations in country 1 and 2, respectively. Since, in the integrated world, final output producers purchase the intermediate goods

from the producers offering the lowest price  $p_x^S = \eta$ , the ROR is  $r_M^i = b\eta^{\frac{\alpha-1}{\alpha}}$  with  $\eta = \min(\eta_1, \eta_2)$ . This implies that the ROR under integration can be equivalently described by  $r_M^i = b\eta^{\frac{\alpha-1}{\alpha}}$  with

$$\eta = \begin{cases} \bar{\eta} + \varepsilon & \text{with } P = 0.25 \\ \bar{\eta} - \varepsilon & \text{with } P = 0.75 \end{cases}$$

The above description immediately implies that the ROR under autarky  $r_M^a$  equals  $b(\bar{\eta} + \varepsilon)^{(\alpha-1)/\alpha}$  with  $P = 0.5$  and  $b(\bar{\eta} - \varepsilon)^{(\alpha-1)/\alpha}$  with  $P = 0.5$ . On the other hand, the ROR under integration  $r_M^i$  is  $b(\bar{\eta} + \varepsilon)^{(\alpha-1)/\alpha}$  with  $P = 0.25$  and  $b(\bar{\eta} - \varepsilon)^{(\alpha-1)/\alpha}$  with  $P = 0.75$ . Moreover,  $r_M^a$  and  $r_M^i$  are Binomial stochastic variables with a variance (per unit of time) given by  $V(u) = P(1 - P)$  and hence:

$$\frac{V(r_M^i)}{V(r_M^a)} = \frac{0.25 * 0.75}{0.5 * 0.5} = 0.75.$$

This completes the proof of Proposition 1.

### 9.2.2 Proposition 2: Comparative statics for $\theta$

The asset allocation share is determined by:

$$\bar{r}_M - r_T = \phi\lambda\gamma [(1 - \phi\lambda\theta)^{-\sigma} - (1 + \phi\lambda\theta)^{-\sigma}].$$

To derive  $\frac{\partial\theta}{\partial\phi}$ , we apply the implicit function theorem. At first notice that the above stated first order condition can be expressed as  $F(\theta; \phi) = 0$ , which implies  $\theta^* = \theta^*(\phi)$ , where  $\theta^*$  denotes the optimal choice of  $\theta$ . Substituting this relation into the first order condition gives  $F[\theta^*(\phi); \phi] = 0$ . Differentiation w.r.t.  $\phi$  gives:

$$\begin{aligned} F_\theta \frac{\partial\theta^*}{\partial\phi} + F_\phi &= 0 \\ \frac{\partial\theta^*}{\partial\phi} &= \frac{-F_\phi}{F_\theta}. \end{aligned}$$

The partial derivative  $F_\theta$  is given by:

$$F_\theta = \gamma\lambda^2\sigma\phi^2(1 - \phi\lambda\theta)^{-1-\sigma} + \gamma\lambda^2\sigma\phi^2(1 + \phi\lambda\theta)^{-1-\sigma}$$

and  $F_\phi$  reads:

$$F_\phi = \gamma\theta\lambda^2\sigma\phi(1 - \phi\lambda\theta)^{-1-\sigma} + \gamma\lambda(1 - \phi\lambda\theta)^{-\sigma} + \gamma\theta\lambda^2\sigma\phi(1 + \phi\lambda\theta)^{-1-\sigma} - \gamma\lambda(1 + \phi\lambda\theta)^{-\sigma}.$$

The ratio  $\frac{-F_\phi}{F_\theta}$  can accordingly be expressed as follows:

$$\frac{-F_\phi}{F_\theta} = -\frac{(1 - \phi\lambda\theta)^{-\sigma} - (1 + \phi\lambda\theta)^{-\sigma}}{\lambda\sigma\phi^2 [(1 - \phi\lambda\theta)^{-1-\sigma} + (1 + \phi\lambda\theta)^{-1-\sigma}]} - \frac{\theta}{\phi}.$$



Since the numerator of the first ratio on the RHS is positive, from the first order condition for  $\theta$  it equals  $\frac{\bar{r}_M - r_T}{\phi\lambda\gamma}$ , and the denominator is positive as well, we have established that:

$$\frac{\partial\theta^*}{\partial\phi} = \frac{-F_\phi}{F_\theta} < 0.$$

This proves Proposition 2 in the main text.

### 9.2.3 Proposition 3: Comparative statics for $\Psi$

The consumption wealth ratio is:

$$\Psi = \frac{(\sigma - 1)r[\theta(\phi)] + \rho}{\sigma} + \frac{\gamma}{\sigma}[2 - (1 + \phi\lambda\theta(\phi))^{1-\sigma} - (1 - \phi\lambda\theta(\phi))^{1-\sigma}]$$

with  $r := \bar{r}_M\theta - r_T(1 - \theta)$ . The partial derivative of the first term on the RHS is:

$$\frac{\partial}{\partial\phi} \frac{(\sigma - 1)r[\theta(\phi)] + \rho}{\sigma} = \frac{(\sigma - 1)}{\sigma} r'(\theta)\theta'(\phi).$$

Since  $r'(\theta) > 0$  and  $\theta'(\phi) < 0$ , we have:

$$\frac{\partial}{\partial\phi} \frac{(\sigma - 1)r[\theta(\phi)] + \rho}{\sigma} = \begin{cases} < 0 & \text{for } \sigma > 1 \\ > 0 & \text{for } \sigma < 1 \end{cases}.$$

Next, consider the partial derivative of  $\frac{\gamma}{\sigma}[2 - (1 + \phi\lambda\theta)^{1-\sigma} - (1 - \phi\lambda\theta)^{1-\sigma}]$  w.r.t.  $\phi$ . Noting the first order condition for  $\theta$ , this derivative can be expressed as:

$$\frac{\partial}{\partial\phi} \frac{\gamma[2 - (1 + \phi\lambda\theta)^{1-\sigma} - (1 - \phi\lambda\theta)^{1-\sigma}]}{\sigma} = \frac{1 - \sigma}{\sigma} [\theta + \phi\theta'(\phi)] \frac{\bar{r}_M - r_T}{\phi\lambda\gamma}.$$

Since  $\theta + \phi\theta'(\phi) > 0$ ,  $0 < \phi < 1$ ,  $\theta'(\phi) < 0$ ,  $|\theta'(\phi)| < \theta(\phi)$ , and  $\bar{r}_M - r_T > 0$  one gets:

$$\frac{\partial}{\partial\phi} \frac{\gamma[2 - (1 + \phi\lambda\theta)^{1-\sigma} - (1 - \phi\lambda\theta)^{1-\sigma}]}{\sigma} = \begin{cases} < 0 & \text{for } \sigma > 1 \\ > 0 & \text{for } \sigma < 1 \end{cases}.$$

Summarizing we have:

$$\frac{\partial}{\partial\phi} \Psi = \begin{cases} < 0 & \text{for } \sigma > 1 \\ > 0 & \text{for } \sigma < 1 \end{cases}.$$

This proves Proposition 3 in the main text.

### 9.2.4 Proposition 4: Comparative statics for $E(dc)/(c dt)$

The expected growth rate of consumption is given by:

$$\frac{E(dc)}{c dt} = \frac{r - \rho}{\sigma} - \frac{\gamma}{\sigma}[2 - (1 + \phi\lambda\theta)^{1-\sigma} - (1 - \phi\lambda\theta)^{1-\sigma}].$$

We want to show that market integration speeds up growth. Let us consider the transition from market integration ( $\phi = \sqrt{0.75}$ ) to autarky ( $\phi = 1$ ), such that, formally, we are considering the consequences of increasing  $\phi$ . The growth rate falls in response to a rise in  $\phi$  provided that:

$$\begin{aligned} \frac{\partial}{\partial \phi} \frac{E(dc)}{c dt} &= \frac{\partial}{\partial \phi} \frac{r - \rho}{\sigma} - \frac{\partial}{\partial \phi} \frac{\gamma[2 - (1 + \phi\lambda\theta)^{1-\sigma} - (1 - \phi\lambda\theta)^{1-\sigma}]}{\sigma} < 0 \\ \iff \frac{\partial}{\partial \phi} \frac{r - \rho}{\sigma} &< \frac{\partial}{\partial \phi} \frac{\gamma[2 - (1 + \phi\lambda\theta)^{1-\sigma} - (1 - \phi\lambda\theta)^{1-\sigma}]}{\sigma}. \end{aligned}$$

The term  $\frac{\partial}{\partial \phi} \frac{r - \rho}{\sigma}$  is unambiguously negative (due to a drop in  $\theta$ ). From the discussion above, we know that for  $\sigma < 1$  it holds true that  $\frac{\partial}{\partial \phi} \frac{\gamma[2 - (1 + \phi\lambda\theta)^{1-\sigma} - (1 - \phi\lambda\theta)^{1-\sigma}]}{\sigma} > 0$ . Hence, in this case,  $\frac{\partial}{\partial \phi} \frac{E(dc)}{c dt} < 0$  is automatically satisfied.

Let us turn to  $\sigma > 1$ , such that  $\frac{\partial}{\partial \phi} \frac{\gamma[2 - (1 + \phi\lambda\theta)^{1-\sigma} - (1 - \phi\lambda\theta)^{1-\sigma}]}{\sigma} < 0$ . Consider  $\frac{\partial}{\partial \phi} \frac{r - \rho}{\sigma}$  which is given by:

$$\frac{\partial}{\partial \phi} \frac{r[\theta(\phi)] - \rho}{\sigma} = \frac{\theta'(\phi)(\bar{r}_M - r_T)}{\sigma}.$$

Next, consider partial derivative of the second term:

$$\frac{\partial}{\partial \phi} \frac{\gamma[2 - (1 + \phi\lambda\theta)^{1-\sigma} - (1 - \phi\lambda\theta)^{1-\sigma}]}{\sigma} = \frac{1 - \sigma}{\sigma} [\theta + \phi\theta'(\phi)] \frac{\bar{r}_M - r_T}{\phi\lambda\gamma}.$$

Putting both together yields:

$$\frac{\theta'(\phi)(\bar{r}_M - r_T)}{\sigma} < \frac{1 - \sigma}{\sigma} [\theta + \phi\theta'(\phi)] \frac{\bar{r}_M - r_T}{\phi\lambda\gamma},$$

which can be simplified to read:

$$\theta'(\phi) < \frac{1 - \sigma}{\sigma} \frac{\theta}{\phi}.$$

Now insert the expression for  $\theta'(\phi)$  derived above. This gives:

$$\begin{aligned} -\frac{(1 - \phi\lambda\theta)^{-\sigma} - (1 + \phi\lambda\theta)^{-\sigma}}{\lambda\sigma\phi^2 [(1 - \phi\lambda\theta)^{-1-\sigma} + (1 + \phi\lambda\theta)^{-1-\sigma}]} - \frac{\theta}{\phi} &< \frac{1 - \sigma}{\sigma} \frac{\theta}{\phi} \\ -\frac{(1 - \phi\lambda\theta)^{-\sigma} - (1 + \phi\lambda\theta)^{-\sigma}}{\lambda\sigma\phi^2 [(1 - \phi\lambda\theta)^{-1-\sigma} + (1 + \phi\lambda\theta)^{-1-\sigma}]} &< \frac{1}{\sigma} \frac{\theta}{\phi}. \end{aligned}$$

Since we know that the LHS is negative, as shown in proof of Proposition 2, and the RHS is positive, the preceding inequality is unambiguously satisfied. This proves Proposition 4 in the main text.

## 9.3 Derivations

### 9.3.1 Decomposition of ROR into deterministic and stochastic component [equ. (13) and (14)]

The ROR of capital invested in the modern sector under autarky  $r_M^a$  and under integration  $r_M^i$  are given by:

$$r_M^a = b\eta^{\frac{\alpha-1}{\alpha}}$$

$$r_M^i = b[\min(\eta_1, \eta_2)]^{\frac{\alpha-1}{\alpha}}$$

with variances  $V(r_M^a) = b^2V(\eta^{\frac{\alpha-1}{\alpha}})$  and  $V(r_M^i) = b^2V\left\{[\min(\eta_1, \eta_2)]^{\frac{\alpha-1}{\alpha}}\right\}$ . Since optimal decisions under uncertainty are predominantly determined by expected value and variance of the stochastic variables involved, one can equivalently represent the above displayed ROR as the sum of a deterministic and a stochastic component with the same expected value and the same variance. Specifically,  $r_M^a = b\eta^{\frac{\alpha-1}{\alpha}}$  (with  $\eta = \bar{\eta} + \varepsilon$  or  $\eta = \bar{\eta} - \varepsilon$ ) can be represented as  $r_M^a = bE\left(\eta^{\frac{\alpha-1}{\alpha}}\right)dt + \lambda dz$ , where  $dz$  is a stochastic increment, either  $dz = \varepsilon$  with  $P = 0.5dt$  or  $dz = -\varepsilon$  with  $P = 0.5dt$ . For instance, the realization  $dz = \varepsilon$  corresponds to  $\eta = \bar{\eta} + \varepsilon$ . Notice that, by construction, the expected values of both representations are identical. Moreover, the parameter  $\lambda$  can be chosen such that the variance of  $b\eta^{\frac{\alpha-1}{\alpha}}$  is identical to the variance of  $bE\left(\eta^{\frac{\alpha-1}{\alpha}}\right)dt + \lambda dz$ .

To apply standard methods of dynamic optimization under (Poisson) uncertainty, the stochastic component of the ROR per period of time is now represented as a composite and symmetric Poisson increment, i.e. we set  $dz = dn_1 - dn_2$ , where  $dn_1$  and  $dn_2$  are described by:

$$dn_1 = \begin{cases} 1 & \text{with } \gamma dt \\ 0 & \text{with } (1 - \gamma)dt \end{cases} \quad \text{and} \quad dn_2 = \begin{cases} 1 & \text{with } \gamma dt \\ 0 & \text{with } (1 - \gamma)dt \end{cases}$$

The variance of  $V[\lambda(dn_1 - dn_2)]$  is equal to  $2\lambda^2\gamma dt - 2\lambda^2\gamma^2 dt^2$  and, hence,  $\lambda$  and  $\gamma$  must be chosen such that  $b^2V(\eta^{\frac{\alpha-1}{\alpha}}) = 2\lambda^2\gamma dt - 2\lambda^2\gamma^2 dt^2$ .

### 9.3.2 The household's flow budget constraint [equ. (15)]

The ROR (modern sector) per period of time under autarky can be expressed as  $r_M^a = \bar{r}_M dt + \lambda(dn_1 - dn_2)$  with  $\bar{r}_M := bE\left(\eta^{\frac{\alpha-1}{\alpha}}\right)$ . Moreover, noting  $V(r_M^i) = 0.75V(r_M^a)$  the ROR (modern sector) per period of time under integration can be expressed as  $r_M^i = \bar{r}_M dt + \sqrt{0.75}\lambda(dn_1 - dn_2)$ . Therefore, the household's flow budget constraint in general form (valid for both the autarky and the integration case) can be expressed as follows:

$$da = [\bar{r}_M\theta a + r_T(1 - \theta)a - c]dt + \theta a\phi\lambda(dn_1 - dn_2).$$

For  $\phi = 1$  this is the flow budget constraint under autarky, while for  $\phi = \sqrt{0.75}$  this is the flow budget constraint under integration. To be precise, this formulation uses the simplifying assumption  $E(r_M^a) = E(r_M^i) = \bar{r}_M = E\left(\eta^{\frac{\alpha-1}{\alpha}}\right)$ . The exact relation, however, reads  $E(r_M^i) = E\left\{[\min(\eta_1, \eta_2)]^{\frac{\alpha-1}{\alpha}}\right\}$ . This assumption is non-critical for the results derived, as explained in the main text.

### 9.3.3 The household's asset allocation decision [equ. (17)]

The Bellman equation for the stochastic dynamic problem under study is (e.g., Dixit and Pindyck, 1994, p. 105):

$$\rho V(a) = \max_{\{c, \theta\}} [u(c) + EdV(a)/dt].$$

Noting the general flow budget constraint, capturing both the autarky and the integration case,  $EdV(a)/dt$  is given by (Wälde, 1999, p. 211):

$$EdV(a)/dt = V'(a)[\bar{r}_M \theta a + r_T(1 - \theta)a - c] + [V(\tilde{a}) - V(a)]\gamma + [V(\tilde{\tilde{a}}) - V(a)]\gamma,$$

where  $\tilde{a} := a + \theta a \phi \lambda$  after  $dn_1 = 1$  and  $\tilde{\tilde{a}} := a - \theta a \phi \lambda$  after  $dn_2 = 1$ . Hence the Bellman equation can be written as:

$$\rho V(a) = \max_{\{c, \theta\}} \left\{ u(c) + V'(a)[\bar{r}_M \theta a + r_T(1 - \theta)a - c] + [V(\tilde{a}) - V(a)]\gamma + [V(\tilde{\tilde{a}}) - V(a)]\gamma \right\}.$$

The necessary first order condition for optimal consumption is:

$$u'(c) = V'(a).$$

The first order condition for the optimal portfolio choice reads:

$$(\bar{r}_M a - r_T a) V'(a) - a \lambda \gamma \phi V'(\tilde{\tilde{a}}) + a \lambda \gamma \phi V'(\tilde{a}) = 0$$

and hence one gets:

$$\bar{r}_M - r_T = \frac{a \lambda \gamma \phi V'(\tilde{\tilde{a}}) - a \lambda \gamma \phi V'(\tilde{a})}{V'(a)}.$$

The linear policy rule, i.e.  $c = \Psi a$  (to be shown below), implies  $\frac{u'(\tilde{c})}{u'(c)} = (1 + \phi \lambda \theta)^{-\sigma}$  and  $\frac{u'(\tilde{\tilde{c}})}{u'(c)} = (1 - \phi \lambda \theta)^{-\sigma}$ . Hence, optimal  $\theta$  is implicitly defined by:

$$\bar{r}_M - r_T = \frac{\lambda \gamma \phi u'(\tilde{\tilde{c}}) - \lambda \gamma \phi u'(\tilde{c})}{u'(c)} = \phi \lambda \gamma [(1 - \phi \lambda \theta)^{-\sigma} - (1 + \phi \lambda \theta)^{-\sigma}].$$

This is equation (17) in the main text.

### 9.3.4 The growth rate of $c$ and $\Psi$ [equ. (18) and (19)]

The optimal growth rate of  $c$  is determined. Subsequently, the constant consumption wealth ratio is derived. Consider the maximized Bellman equation:

$$\rho V(a) = u(c(a)) + V'(a)[\bar{r}_M \theta a + r_T(1-\theta)a - c(a)] + [V(\tilde{a}) - V(a)] \gamma + [V(\tilde{\tilde{a}}) - V(a)] \gamma.$$

At first, we compute the partial derivative of the Bellman equation w.r.t. to  $a$ :

$$\begin{aligned} \rho V'(a) &= c'(a)u'(c(a)) + [r_T(1-\theta) + \bar{r}_M \theta - c'(a)] V'(a) \\ &\quad + \gamma [(1 - \phi\lambda\theta)V'(a(1 - \phi\lambda\theta)) - V'(a)] \\ &\quad + \gamma [(1 + \phi\lambda\theta)V'(a(1 + \phi\lambda\theta)) - V'(a)] \\ &\quad + [\bar{r}_M \theta a + r_T(1-\theta)a - c(a)] V''(a). \end{aligned}$$

Solving for  $V''(a)[\bar{r}_M \theta a + r_T(1-\theta)a - c(a)]dt$  gives:

$$\begin{aligned} V''(a)[\bar{r}_M \theta a + r_T(1-\theta)a - c(a)]dt &= [\rho - (\bar{r}_M \theta + r_T(1-\theta))] V'(a)dt \\ &\quad - \gamma [(1 - \phi\lambda\theta)V'(a(1 - \phi\lambda\theta)) - V'(a)] dt \\ &\quad - \gamma [(1 + \phi\lambda\theta)V'(a(1 + \phi\lambda\theta)) - V'(a)] dt. \end{aligned}$$

Next, the differential  $dV'(a)$  is derived by applying Itô's Lemma for Poisson processes (Sennewald and Wälde, 2005):

$$dV'(a) = V''(a)[\bar{r}_M \theta a + r_T(1-\theta)a - c]dt + [V'(\tilde{a}) - V'(a)] dn_1 + [V'(\tilde{\tilde{a}}) - V'(a)] dn_2$$

Replacing the first term on the RHS by the expression derived above yields:

$$\begin{aligned} dV'(a) &= [\rho - (\bar{r}_M \theta + r_T(1-\theta))] V'(a)dt \\ &\quad - \gamma [(1 - \phi\lambda\theta)V'(a(1 - \phi\lambda\theta)) - V'(a)] dt \\ &\quad - \gamma [(1 + \phi\lambda\theta)V'(a(1 + \phi\lambda\theta)) - V'(a)] dt \\ &\quad + [V'(\tilde{a}) - V'(a)] dn_1 + [V'(\tilde{\tilde{a}}) - V'(a)] dn_2. \end{aligned}$$

Replacing  $V'(a)$  by  $u'(c)$ ,  $V'(\tilde{a})$  by  $u'(\tilde{c})$ , and  $V'(\tilde{\tilde{a}})$  by  $u'(\tilde{\tilde{c}})$ , and taking into account that, for CRRA utility,  $\frac{u'(\tilde{c})(1+\phi\lambda\theta)}{u'(\tilde{c})} = (1 + \phi\lambda\theta)^{1-\sigma}$  and  $\frac{u'(\tilde{\tilde{c}})(1-\phi\lambda\theta)}{u'(\tilde{\tilde{c}})} = (1 - \phi\lambda\theta)^{1-\sigma}$  finally leads to:

$$\begin{aligned} du'(c) &= u'(c) [\rho - (\bar{r}_M \theta + r_T(1-\theta)) + \gamma(2 - (1 - \phi\lambda\theta)^{1-\sigma} - (1 + \phi\lambda\theta)^{1-\sigma})] dt \\ &\quad + [u'(\tilde{c}) - u'(c)] dn_1 + [u'(\tilde{\tilde{c}}) - u'(c)] dn_2. \end{aligned}$$

Next determine  $dc$ . First, note that the preceding function is a SDE in  $u'(c)$  and, second, define a function  $f[u'(c)] = c$  and then determine (using Itô's Lemma for Poisson processes)  $df(\cdot) = dc$ . In addition, observe that:

$$\frac{df[u'(c)]}{du'(c)} = \frac{dc}{du'(c)} = \frac{1}{u''(c)}.$$

Assuming that preferences are CRRA, implying  $\sigma = -\frac{u''(c)c}{u'(c)}$ , leads to:

$$dc = \frac{c}{\sigma} [(\bar{r}_M\theta + r_T(1-\theta)) - \rho - \gamma(2 - (1 - \phi\lambda\theta)^{1-\sigma} - (1 + \phi\lambda\theta)^{1-\sigma})] dt + (\tilde{c} - c)dn_1 + (\tilde{\tilde{c}} - c)dn_2.$$

Taking  $(\tilde{c}-c)\gamma = (\tilde{\tilde{c}}-c)\gamma$  into account, the expected growth rate may be expressed as:

$$\frac{E(dc)}{c dt} = \frac{r - \rho}{\sigma} - \frac{\gamma}{\sigma} [2 - (1 + \phi\lambda\theta)^{1-\sigma} - (1 - \phi\lambda\theta)^{1-\sigma}].$$

This is equation (19) in the main text.

Next we turn to the expected growth rate of assets which results from

$$da = [\bar{r}_M\theta a + r_T(1-\theta)a - c] dt + \theta a \phi \lambda (dn_1 - dn_2)$$

and can hence be expressed as:

$$\frac{E(da)}{a dt} = \bar{r}_M\theta + r_T(1-\theta) - \Psi,$$

where  $\Psi = c/a$ . Since, in a steady state,  $\theta$  is constant,  $\Psi$  must be constant as well. The consumption wealth ratio then follows from  $\frac{E(dc)}{c dt} = \frac{E(da)}{a dt}$  which yields:

$$\Psi = \frac{(\sigma - 1)r + \rho}{\sigma} + \frac{\gamma}{\sigma} [2 - (1 + \phi\lambda\theta)^{1-\sigma} - (1 - \phi\lambda\theta)^{1-\sigma}].$$

This is equation (18) in the main text.

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