

# Financial Inclusion, Productivity Shocks, and Consumption Volatility in Emerging Economies

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## Abstract

How does access to finance impact consumption volatility? Theory and evidence from advanced economies suggests that greater household access to finance smooths consumption. Evidence from emerging markets, where consumption is usually more volatile than income, indicates that financial reform further increases the volatility of consumption relative to output. This puzzle is addressed in the framework of an emerging economy model in which households face

shocks to trend growth rate, and a fraction of them are financially constrained, with no access to financial services. Unconstrained households can respond to shocks to trend growth by raising current consumption more than the rise in current income. Financial reform increases the share of such households, leading to greater relative consumption volatility. Calibration of the model for pre- and post-financial reform in India provides support for the model's key predictions.

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# **Financial Inclusion, Productivity Shocks, and Consumption Volatility in Emerging Economies**

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## INTRODUCTION

Emerging economies have been seen to witness an increase in consumption volatility relative to output volatility after financial development. This behaviour appears puzzling since traditional models and evidence from advanced economies suggests that consumption should become smoother after financial constraints are reduced. This puzzle can be explained in a model featuring financial constraints and shocks to trend growth of productivity. The model predicts that relative consumption volatility rises when more consumers can access financial services.

The presence of financial constraints, such as credit constraints or lack of access to financial services in an economy, explains the excess volatility of consumption and its sensitivity to anticipated income fluctuations. A model featuring financially constrained consumers predicts that consumption cannot be smoothed fully. But in such a model, the volatility of consumption can be at least as high as income volatility or, at most, one. Further, if constraints are eased, the model predicts a reduction in relative consumption volatility.

Another feature of emerging economy models is the presence of shocks to trend growth of productivity. Large shocks to the permanent component of income originated from frequent policy regime shifts in emerging economies, relative to transitory income shocks, explain larger fluctuations in consumption relative to output fluctuations (Aguiar and Gopinath 2007). Unlike developed countries characterised by large transitory movements in income around the trend, shocks to trend growth are the primary source of fluctuations in emerging economies. When households anticipate a higher growth rate of income, which eventually leads to a rise in future income, they respond to this permanent income shock by increasing current consumption more than the rise in current income via borrowing against the future income or reducing current savings. As a result, consumption fluctuates more than income in emerging economies. This feature results in the relative

volatility of consumption in emerging economies becoming greater than one.

A common feature of reform in emerging economies is financial sector reform. The increase in the access of households to finance resulting from reform allows households to smooth consumption over their lifetimes. But at the same time, emerging economies witness large shocks to the permanent component of income, relative to transitory income shocks. The combination of the response of households to permanent income shocks and the easing of financial constraints can yield an increase in the relative volatility of consumption.

The goal of this paper is to understand the joint impact of easing of financial constraints and permanent income shock on consumption volatility. This is analysed in a dynamic general equilibrium model with heterogeneous type agents. The model assumes that some households in the economy do not have access to finance. They can neither save nor borrow. These financially constrained households cannot smooth consumption over their lifetimes. The rest of the households in the economy are unconstrained and respond to a perceived income shock by smoothing consumption. Shocks to income that are perceived to be permanent lead to an increase in current period consumption higher than the increase in current period income. Only unconstrained households can increase consumption by more than the increase in income, either by borrowing against future income or reducing current savings. Constrained households can only increase consumption by the amount income has increased. Financial sector reform allows more households to access financial services. Now more households become unconstrained and can respond to the income shock that they perceive to be permanent. The key prediction of this model is that financial development in an emerging economy leads to an increase in relative consumption volatility.

This prediction can be tested. The model is calibrated to Indian data for the pre- and post-reform years. All of the parameters, except for the share of

financially constrained consumers, are kept unchanged. Financial inclusion is captured via a reduction in the fraction of constrained households in the post reform period. The results support the model's key prediction.

This paper makes a contribution towards understanding the joint impact of financial development and permanent income shock on consumption volatility. It contributes to a growing literature that studies the effects of financial frictions on volatility. Earlier work mainly analyses the effect of domestic financial system development on output and consumption volatility through its effect on firms (Aghion et al. 2004, 2010). Some papers focus on the impact of financial globalisation on volatility (Aghion et al. 2004; Buch et al. 2005; Leblebicioglu 2009). The effect of domestic financial system development on output and consumption volatility is explored in a limited strand of literature. Iyigun and Owen (2004) propose a theory of income inequality in rich and poor countries as the cause of consumption volatility whose mechanics partly resemble those of the present model, once appropriately re-interpreted.

The model takes into account the broadly acknowledged fact that in emerging economies all consumers do not have access to finance (Honohan 2006). Financially constrained households are modelled as in Hayashi (1982) and Campbell and Mankiw (1991). The framework includes shocks to trend growth as in Aguiar and Gopinath (2007).

The rest of the paper is organised as follows: The Consumption Volatility and Financial Development section presents evidence on relative consumption volatility and financial development in emerging economies. The Consumption Volatility and Permanent versus Transitory Income Shocks section discusses the role of the relative magnitude of permanent and transitory income shocks for consumption volatility in developed vis-à-vis emerging economies. The Financial Frictions and Consumption Volatility: Theoretical Framework section presents

the model and its predictions. The Case Study: Evidence for India section contains the calibration exercise and results. The Financial Development, Permanent Income Shock, and Relative Consumption Volatility in a Small Open Economy section presents the implications in a small open economy setup. The final section concludes.

#### CONSUMPTION VOLATILITY AND FINANCIAL DEVELOPMENT

Recent empirical evidence on emerging economy business cycles shows an increase in the volatility of consumption relative to that of output after financial sector reform in Asia, Turkey, and India (Kim et al. 2003; Alp et al. 2012; Ghate et al. 2013). The relative volatility of consumption in the pre- and post-financial sector reform period for some developing countries are estimated (table 1). The choice of the date on which reform took place is based on Kim et al. (2003), Singh et al. (2005), Rodrik (2008), Alp et al. (2012), and Aslund (2012). The analysis is based on annual data for a set of emerging economies.<sup>1</sup> The volatility of consumption relative to that of output in these countries, in the pre- and post-reform period, shows that many emerging economies exhibit similar behaviour in that relative consumption volatility increases after reform (table 1).

Financial development has been a major component of reform. A commonly used indicator of financial development, namely, total bank deposits to GDP ratio, for a set of emerging economies, on average, shows a rise in the indicator over time (figure 1). The rising trend in the ratio is also visible for individual countries (figure 1).

The indicators on financial depth, depicted by the density of commercial bank branches and depositors with commercial banks in emerging economies, in the beginning and in the end of the last decade, indicate an increase in access of

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<sup>1</sup> The span of the analysis varies across countries given the availability of the data. Table S1.1 in the Supplemental Appendix S1, lists period of analysis for each country. The reform date for each region, and the sources of the documentations indicating the reform dates are also reported in this table.

households to finance (table 2).

The above evidence suggests that the relative volatility of consumption rises after financial sector reform. This appears puzzling and cannot be explained by the existing literature. It supports the evidence in Kim et al. (2003), Alp et al. (2012), and Ghate et al. (2013), who allude to the increase in relative consumption volatility after financial sector reform.

#### CONSUMPTION VOLATILITY AND PERMANENT VERSUS TRANSITORY INCOME SHOCKS

Empirical literature on business cycle stylised facts document business cycle properties in developed economies (Kydland and Prescott 1990; Backus and Kehoe 1992; Stock and Watson 1999; King and Rebelo 1999) and developing countries (Agenor et al. 2000; Rand and Tarp 2002; Male 2010). One of the key business cycle features that distinguishes emerging economies from advanced countries is the greater fluctuations in consumption relative to income fluctuations. Aguiar and Gopinath (2007) relate this difference in consumption behaviour in the two sets of countries, to the relative magnitude of permanent and transitory shocks to income.

The authors estimate a standard small open economy real business cycle model for Mexico, as a representative of the emerging economies, and Canada, representing advanced countries. The main finding is that large shocks to the growth rate of permanent components of productivity are the primary sources of fluctuations in emerging economies. In contrast, advanced economies are characterised by fluctuations around a stable trend, caused by large shocks to transitory component of productivity. The differences in technology shock processes cause households to respond differently to income shocks in developed and emerging economies. When households anticipate a higher growth rate of income which eventually leads to a rise in future income, they respond to this permanent income shock by increasing current consumption more than the rise in current income via borrowing against the future income or reducing current

savings. As a result, consumption fluctuates more than income in emerging economies. This feature results in the relative volatility of consumption in emerging economies being greater than one.

*Positive Correlation between the Size of Trend Growth Shock and Relative Consumption Volatility: Evidence from Literature*

The positive correlation between the magnitude of shocks to trend growth and relative consumption volatility, found in the literature, is documented in table 3. The third and fifth columns of the table show technological shock processes for Mexico and Canada, along with output and consumption volatilities estimated from the model in Aguiar and Gopinath (2007). The second and fourth columns also document the empirical volatilities in output and consumption for these two countries. The table shows that Mexico, with consumption volatility relative to output volatility greater than one, is characterised by a larger shock to the growth rate of permanent component of technology  $\sigma_g$  compared to the transitory shock  $\sigma_a$ . In contrast, Canada, with a relative consumption volatility less than one, is characterised by larger transitory shocks compared to fluctuation in the permanent component of productivity.

Similarly, Naoussi and Tripier (2013) estimate a real business cycle model with transitory and trend shocks to productivity for eighty-two countries, including developed, emerging, and Sub-Saharan African (SSA) countries. They find that magnitudes of trend shocks are positively correlated with relative consumption volatilities. Columns 6 to 11 in table 3 summarise their findings. Relative consumption volatilities and shock to trend growth rate are found to be highest for SSA countries, followed by emerging and developed economies.

Finally, column 12 of table 3 shows the nature of technology shock processes for India. The estimation of the technology shock processes in India are

outlined in the following section.

*Decomposition of Indian Total Factor Productivity (TFP) Series to Permanent and Transitory Components*

To have an account of transitory and trend growth shock in the Indian TFP series, the series is decomposed into permanent and transitory components using Kalman filter. First, the TFP series for India is estimated following an aggregate production function approach. The aggregate production function, representing the production sector in the model outlined in the next section, is defined following Aguiar and Gopinath (2007) as

$$\begin{aligned} Y_t &= e^{a_t} K_t^{1-\alpha} (\Gamma_t)^\alpha, \\ \frac{\Gamma_t}{\Gamma_{t-1}} &= g_t, \end{aligned} \quad (1)$$

where  $K_t$  is the aggregate stock of capital and  $\alpha \in (0,1)$  denotes labour's share of output. Households are assumed to supply unit labour inelastically. The parameters  $a_t$  and  $\Gamma_t$  represent productivity processes. The two productivity processes are characterised by different stochastic properties. The parameter  $a_t$  captures a transitory movement in productivity and is characterised by the following AR(1) process:

$$a_t = \rho_a a_{t-1} + \check{\alpha}_t^a; \quad |\rho_a| < 1, \quad \check{\alpha}_t^a \sim N(0, \sigma_a^2). \quad (2)$$

The parameter  $\Gamma_t$  represents the cumulative product of growth shocks as follows:

$$\ln \left( \frac{g_t}{\mu_g} \right) = \rho_g \ln \left( \frac{g_{t-1}}{\mu_g} \right) + \check{\alpha}_t^g; \quad |\rho_g| < 1, \quad \check{\alpha}_t^g : N(0, \sigma_g^2), \quad (3)$$

where  $\mu_g - 1$  is the long-run mean trend growth rate. The two different productivity processes are assumed to distinguish shock process in the level of productivity  $a_t$  and the growth rate of productivity  $g_t$ . The growth shocks are incorporated in a labour-augmenting way to ensure the existence of a steady state where all variables

grow at the rate  $\mu_g$  and the tractability of analysis of cyclical properties of the model economy. In this analysis, the cyclical component of a variable  $X_t$ , that is, the deviation of the variable from its trend path is defined as  $x_t = \frac{X_t}{\Gamma_{t-1}}$ .

The Solow residual from the aggregate production function captures productivity processes that contains a transitory and a permanent component:

$$sr_t = a_t + \alpha \ln \Gamma_t = \ln Y_t - (1 - \alpha) \ln K_t. \quad (4)$$

Since, the households supply unit labour inelastically and total mass of households is normalised to one, equation (4) measures the Solow residual in terms of per capita output and capital stock. In estimating the Solow residual for India, GDP at factor cost and net fixed capital stock, both in 2004–05 constant prices, proxy for output and capital stock, respectively. The data on GDP and net fixed capital stock are sourced from National Accounts Statistics. The labour force data are sourced from the World Bank. The value of labour share is set to 0.7 from Verma (2008). Given the availability of data on labour force and capital stock, the Solow residual series spans 1980–2009.

The transitory and permanent components in the Solow residual series for India are estimated using the Kalman filter. The underlying model is the following: the Solow residual series  $sr_t$  is a sum of a trend component  $T_t$  and a transitory or cyclical component  $C_t$ :

$$\begin{aligned} sr_t &= T_t + C_t + V_t; \quad V_t \sim N(0, \sigma_V^2), \\ T_t &= d + T_{t-1} + W_{1t}; \quad W_{1t} \sim N(0, \sigma_{W1}^2), \\ C_t &= \rho_c C_{t-1} + W_{2t}; \quad |\rho_c| < 1; \quad W_{2t} \sim N(0, \sigma_{W2}^2). \end{aligned} \quad (5)$$

where  $V_t$  represents measurement error. The trend component is assumed to follow a random walk process. This Trend-Cycle model in equation (5) can be represented in state-space form as:

$$sr_t = [1 \quad 1] \begin{pmatrix} T_t \\ C_t \end{pmatrix} + V_t, \quad (6)$$

$$\begin{pmatrix} T_t \\ C_t \end{pmatrix} = \begin{pmatrix} d \\ 0 \end{pmatrix} + \begin{pmatrix} 1 & 0 \\ 0 & \rho_c \end{pmatrix} \begin{pmatrix} T_{t-1} \\ C_{t-1} \end{pmatrix} + \begin{pmatrix} W_{1t} \\ W_{2t} \end{pmatrix}.$$

The first expression in equation (6) represents the observation equation in terms of the unobserved states. The second equation represents the transition dynamics of the state variables. Figure 2 depicts the Kalman-filtered trend growth rate and cyclical components of the Solow residual for India.

Decomposition of Indian TFP in permanent and transitory components shows that shocks to trend growth are a major source of fluctuations in Indian business cycle. The Kalman filtered estimate of  $\sigma_{w_2} = 0.32$  provides a measure of transitory shock  $\sigma_a$ , and the estimate of  $\rho_c = 0.76$  gives the degree of persistence in transitory component of TFP. Next, an AR(1) model is fitted to the growth rate of the estimated permanent component of TFP. The persistence in the trend growth  $\rho_g$  is found to be 0.27, while the estimate of  $\sigma_g$  is 1.59. The value of  $\sigma_g$  compared to  $\sigma_a$  indicates that the shock to trend growth rate is substantially higher than the transitory shock. These estimates are shown in table 3 along with output and consumption volatilities during the period spanning the TFP series.

#### FINANCIAL FRICTIONS AND CONSUMPTION VOLATILITY: THEORETICAL FRAMEWORK

The theoretical literature on finance and macroeconomic volatility explores how financial integration and financial development affect output and consumption volatility through the channel of firms and households (Bernanke and Gertler 1989; Greenwald and Stiglitz 1993; Aghion et al. 2004; Iyigun and Owen 2004; Buch et al. 2005; Leblebicioglu 2009; Aghion et al. 2010). The effect of financial integration on macroeconomic volatility dominates the literature. A limited strand of literature explores the role of domestic financial development in determining the

pattern of macroeconomic fluctuations, and the bulk of it focuses on the channel of firms (Bernanke and Gertler 1989; Greenwald and Stiglitz 1993; Aghion et al. 2010).

The early literature predicts that financial development reduces macroeconomic fluctuations (Bernanke and Gertler 1989; Greenwald and Stiglitz 1993). More recent literature suggests that the nature of relationship between financial development and macroeconomic volatility can be nonlinear (Aghion et al. 2004) and may depend on several factors, such as the composition of short-term and long-term investments in the economy (Aghion et al. 2010).

### *The Model*

Consider a closed economy that is populated by a continuum of infinitely lived households and firms, both of measure unity. There exists a fraction  $\lambda$  of households with no access to banking or other instruments to save. These consumers, who may be referred to as non-Ricardian households, are liquidity-constrained and unable to save or borrow to smooth consumption. They have no assets and spend all their current disposable labour income on consumption in each period.

Labour supply is inelastic as no labour-leisure choice is made by the representative household. Emerging economies are characterised by large size of informal employment where average hours of work are found to be higher than that in the formal sector employment (Blunch et al. 2001; International Labour Organization 2012). For instance, studies found that informal sector workers worked on average fifteen hours more than their counterparts in the formal sector (Blunch et al. 2001).<sup>2</sup> Hence, in an emerging economy setup, it is reasonable to

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<sup>2</sup> In India, more than 90% of the workforce and about 50% of the national product are accounted for by the informal economy (Report of the Committee on Unorganised Sector Statistics 2012). According to National Sample Survey Organisation (2004–05), of the total workers, 82% in the rural areas and 72% in the urban areas are engaged in informal sector. In terms of absolute numbers, out of the total 465 million people employed in the formal and

assume that households allocate their available labour-time to production as much as possible. The representative household is assumed to supply one unit of labour inelastically.

Both Ricardian and liquidity-constrained households have identical preferences defined over a single commodity,

$$U(C_t^i) = \ln(C_t^i), \quad i = R, L, \quad (7)$$

where  $C_t^i$  denotes total consumption of the household of type  $i$ . Ricardian households are indexed as  $R$  and liquidity-constrained households as  $L$ .

A Ricardian household maximises discounted stream of utility,

$$V_t = E_t \sum_{\tau=0}^{\infty} \beta^{\tau} \log(C_{t+\tau}^R), \quad (8)$$

subject to the following budget constraint,

$$C_t^R + I_t^R = R_t K_t^R + W_t, \quad (9)$$

where  $\beta \in (0,1)$  denotes the subjective discount factor. Here  $C_t^R$  is total consumption of the Ricardian household in period  $t$ . The variables  $I_t^R$  and  $K_t^R$  denote investment and capital stock of the household, respectively. The economy-wide return to capital and wage rate are given by  $R_t$  and  $W_t$ . In each period, the Ricardian household divides her disposable income, comprised of wage and rental income, into consumption and savings.

The stock of capital of the representative Ricardian household evolves via the following law of motion,

$$K_{t+1}^R = (1 - \delta)K_t^R + I_t^R - \frac{\phi}{2} \left( \frac{K_{t+1}^R}{K_t^R} - \mu_g \right)^2 K_t^R. \quad (10)$$

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informal sectors, only 28 million people (6% of the total employment) are employed in the formal sector, while 437 million workers (94% of the total employment) are in the informal sector (National Sample Survey Organisation 2009–10), (<http://labour.gov.in/content/aboutus/about-ministry.php>). Data on hours worked are not officially published in India. The officially published employment data captures the employment scenario in the formal sector, which constitutes only 6% of the total employment.

The investment is subject to quadratic capital adjustment cost as in Aguiar and Gopinath (2007).

Households who do not have access to financial services cannot save or borrow. Their behaviour is thus different from that of Ricardian consumers. Liquidity-constrained households maximise instantaneous utility  $\log C_t^L$  subject to the following budget constraint in each period,

$$C_t^L = W_t, \quad (11)$$

where  $C_t^L$  is total consumption of the liquidity-constrained household in period  $t$ . In each period, a liquidity-constrained household consumes its entire disposable income comprised of wage income.

The aggregate consumption is the weighted average of consumption by the liquidity-constrained households and the Ricardian households. The weights are the share of each type of households in the population.

$$C_t = \lambda C_t^L + (1-\lambda)C_t^R. \quad (12)$$

The aggregate capital stock and investment are, respectively, the following

$$K_t = (1-\lambda)K_t^R, \quad I_t = (1-\lambda)I_t^R, \quad (13)$$

A representative firm produces a homogeneous good, by hiring one unit of labour from households and combining it with capital. The aggregate output is produced by Cobb Douglas technology that uses capital and unit labour as inputs:

$$Y_t = e^{a_t} [(1-\lambda)K_t^R]^{1-\alpha} \Gamma_t^\alpha, \quad (14)$$

where  $\alpha \in (0,1)$  represents labour's share of output and  $e^{a_t}$  denotes the transitory component of total factor productivity. Here  $\Gamma_t$  is the permanent component of productivity. The two productivity processes are characterised by the following stochastic properties: total factor productivity evolves according to an AR(1) process as follows:

$$a_t = \rho_a a_{t-1} + \varepsilon_t^a, \quad (15)$$

with  $|\rho_a| < 1$  and  $\varepsilon_t^a$  represents *iid* draws from a normal distribution with zero mean and standard deviation  $\sigma_a$ .

Following Aguiar and Gopinath (2007), the growth rate of labour productivity  $\Gamma_t$  is defined as

$$\Gamma_t = g_t \Gamma_{t-1}. \quad (16)$$

The growth rate of labour productivity  $g_t$  follows an AR(1) process of the form:

$$\ln \left( \frac{g_t}{\mu_g} \right) = \rho_g \ln \left( \frac{g_{t-1}}{\mu_g} \right) + \varepsilon_t^g; \varepsilon_t^g : N(0, \sigma_g^2) \quad (17)$$

The resource constraint of the economy is given by

$$C_t + I_t = Y_t \quad (18)$$

In a closed economy, total output is allocated between total consumption and investment as indicated by equation (18).

Since the realisation of  $g$  permanently influences  $\Gamma$ , output is nonstationary with a stochastic trend. Output, consumption, investment, and capital stock are detrended by normalising these variables with respect to the trend productivity through period  $t-1$ . For any variable  $X$ , its detrended counterpart is defined as

$$x_t = \frac{X_t}{\Gamma_{t-1}}.$$

With the initial capital stock  $K_0$ , the competitive equilibrium is defined as a set of prices and quantities  $(R_t, W_t, y_t, c_t, c_t^R, c_t^L, i_t, k_t)$ , given the sequence of shocks to TFP and labour productivity growth, that solves the maximisation problem of the household, optimisation by the firms, and satisfies the resource constraint of the economy.

### *Predictions*

After normalisation of the variables by labour productivity in the previous

period, the system of equations driving the dynamics of the model economy become

$$\begin{aligned}
1 &= \beta E_{t-1} \left[ \Omega_t \frac{c_{t-1}^R}{c_t^R g_t} \right], \\
\Omega_t &= (1-\alpha)e^{a_t} (1-\lambda)^{1-\alpha} (k_t^R)^{-\alpha} g_t^\alpha + (1-\delta), \\
c_t^R &= \frac{(1-\alpha\lambda)}{1-\lambda} e^{a_t} [(1-\lambda)k_t^R]^{-\alpha} g_t^\alpha + (1-\delta)k_t^R \\
&\quad - g_t k_{t+1}^R - (\phi/2) \left( \frac{k_{t+1}^R g_t}{k_t} - \mu_g \right)^2 k_t^R, \\
a_t &= \rho_a a_{t-1} + \varepsilon_t^a, \\
\ln \left( \frac{g_t}{\mu_g} \right) &= \rho_g \ln \left( \frac{g_{t-1}}{\mu_g} \right) + \varepsilon_t^g.
\end{aligned} \tag{19}$$

The first equation in the system of equations (19) describes intertemporal allocation of consumption by the Ricardian consumers where  $\Omega_t$  is the gross return to capital. The third equation pertains to the resource constraint of the economy, after taking into account the consumption of liquidity-constrained households as in equation (11), total consumption in equation (12), dynamics of capital accumulation by the Ricardian households in equation (10), stock of capital and investment in the economy given in equation (13), and making use of the fact that

$$w_t = \frac{W_t}{\Gamma_{t-1}} = \alpha e^{a_t} [(1-\lambda)k_t^R]^{1-\alpha} g_t^\alpha.$$

After log-linearising the system of equations (19) and given the total consumption of the economy as in equation (12), and making use of the equation (11) and the fact that  $W_t = \alpha Y_t$  implying  $\tilde{c}_t^L = \tilde{y}_t$ , one can arrive at the volatility of consumption relative to output as,

$$\frac{\sigma_{\tilde{c}}^2}{\sigma_{\tilde{y}}^2} = \left( \frac{c^{R*}}{c^*} \right)^2 (1-\lambda)^2 \frac{\sigma_{\tilde{c}^R}^2}{\sigma_{\tilde{y}}^2} + \left( \frac{c^{L*}}{c^*} \right)^2 \lambda^2. \tag{20}$$

Here the fluctuations in a Ricardian household's consumption and that in total

output are, respectively,

$$\sigma_{\tilde{c}^R}^2 = \left[ \frac{a_2^2 b_1^2}{1-a_1^2} + b_2^2 \right] \sigma_a^2 + \left[ \frac{a_2^2 d_1^2}{1-a_1^2} + d_2^2 \right] \sigma_g^2,$$

$$\sigma_{\tilde{y}}^2 = \left[ 1 + \frac{(1-\alpha)^2 b_1^2}{1-a_1^2} \right] \sigma_a^2 + \left[ \alpha^2 + \frac{(1-\alpha)^2 d_1^2}{1-a_1^2} \right] \sigma_g^2.$$

The Supplemental Appendix S2 describes the solution method in details.

The effects of transitory and permanent income shocks on the volatility of consumption relative to volatility of output in the economy can be summarised as follows.

**Proposition 1** *With everything else remaining unchanged,*

(i) *Volatility of consumption of a liquidity-constrained household relative to output volatility is always unity, that is,  $\frac{\sigma_{\tilde{c}^L}}{\sigma_{\tilde{y}}} = 1$ , when  $\sigma_{\varepsilon^a} > 0$ ;  $\sigma_{\varepsilon^g} > 0$ .*

(ii) *Due to a transitory shock in income, both volatility of consumption of a Ricardian household relative to output volatility and the volatility of total consumption relative to output volatility are lower than one, irrespective of the share of liquidity-constrained households in the population, that is,  $\frac{\sigma_{\tilde{c}^R}}{\sigma_{\tilde{y}}} < 1$  and*

*$\frac{\sigma_{\tilde{c}}}{\sigma_{\tilde{y}}} < 1$  for  $\lambda \in [0,1)$ , when  $\sigma_{\varepsilon^a} > 0$ ;  $\sigma_{\varepsilon^g} = 0$ .*

(iii) *Due to a shock to the trend growth of income, volatility of consumption of a Ricardian household relative to volatility of output always exceeds one, irrespective of the share of liquidity-constrained households in the economy, while the volatility of total consumption relative to output volatility depends on the share of liquidity-constrained households in the economy, that is,  $\frac{\sigma_{\tilde{c}^R}}{\sigma_{\tilde{y}}} > 1$ , and  $\frac{\sigma_{\tilde{c}}}{\sigma_{\tilde{y}}} \geq 1$ , for*

*$\lambda \in [0,1)$ , when  $\sigma_{\varepsilon^a} = 0$ ;  $\sigma_{\varepsilon^g} > 0$ .*

(iv) *In the presence of shock to the trend growth rate, both volatility of consumption of a Ricardian household relative to output volatility and the volatility of total consumption relative to volatility of output increases when the share of liquidity-constrained households in the economy decreases, that is,*

$$\frac{\partial \left( \frac{\sigma_{\tilde{c}^R}}{\sigma_{\tilde{y}}} \right)}{\partial \lambda} < 0, \text{ and } \frac{\partial \left( \frac{\sigma_{\tilde{c}}}{\sigma_{\tilde{y}}} \right)}{\partial \lambda} < 0, \text{ for } \lambda \in [0,1), \text{ when } \sigma_{\varepsilon^a} = 0; \sigma_{\varepsilon^g} > 0.$$

The proof of Proposition 1 is presented in the Supplemental Appendix S2 in details.

Liquidity-constrained households who have no access to savings instruments can respond to any change in income by changing consumption by the amount of changed income. Hence volatility of consumption of a liquidity-constrained household relative to output volatility is always one irrespective of the nature of shock.

In response to a transitory income shock, a Ricardian household smooths consumption by re-allocating changed income between consumption and savings. Hence consumption fluctuates by a lesser amount compared to income fluctuation. Hence consumption volatility of a Ricardian household relative to output volatility, in response to a transitory income shock, is always less than one, irrespective of the level of financial development. In this scenario, the relative volatility of total consumption, when total consumption is a weighted average of the relative consumption volatility of a Ricardian household and that of a liquidity-constrained household, is also less than one in all states of financial development.<sup>3</sup>

Ricardian households perceive a rise in income in the future following a permanent income shock. They respond to it by raising current consumption more

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<sup>3</sup> The weights correspond to a combination of the share of consumption of the respective household type in total consumption and the share of such households in total population.

than the rise in current income by borrowing against future income or reducing current savings. Thus, relative volatility of consumption of a Ricardian household with respect to output volatility is greater than one. Relative volatility of total consumption, when total consumption is a weighted average of the relative consumption volatility of a Ricardian household and that of a liquidity-constrained household, may be smaller or higher than one depending on the size of  $\lambda$ .

Financial development reduces the share of liquidity-constrained households in the economy and hence allows more people to respond to the permanent income shock by raising current consumption more than the rise in current income. As a result, volatility of total consumption relative to output volatility increases with financial development.

Combining these observations, the main theoretical prediction of the model can be stated as follows:

**Main prediction:** Other things unchanged, under the occurrence of permanent income shock, financial development leads to a rise in the volatility of consumption in the economy relative to output volatility.<sup>4</sup>

The main prediction is tested by calibrating the model economy to Indian data. The hypothesis is tested for an emerging economy where relative consumption volatility shows an increase after witnessing of financial sector development.

#### CASE STUDY: EVIDENCE FOR INDIA

The model is calibrated for India, an emerging economy which has witnessed financial sector reform. Ang (2011) finds that financial liberalisation

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<sup>4</sup> It follows from the implications of the main prediction of the model that in response to a negative permanent income shock, Ricardian households reduce current consumption by more than the decline in current income and raise investment in order to smooth consumption over the lifetime. Financial development will allow more people to respond to the negative income shock by reducing current consumption more than the fall in income. Volatility of total consumption relative to output volatility thus increases with financial development under negative trend growth shocks as well.

increases fluctuations in consumption in India during 1950–2005. Also, relative to income volatility, consumption volatility in India increased after reform (Ghate et al. 2013).

India has witnessed development of its domestic financial sector in the post-reform period, while remaining fairly closed in terms of capital account openness even after the reform. Thus India serves as an example of an emerging economy, with a low level of financial integration and a moderate expansion of domestic financial services. Financial development indicators show expansion of financial services in India from the pre- to post-reform periods (figure 3). Interestingly, the country witnessed a small decline in banking services before witnessing a sharp increase. This period is included in the post-reform sample to achieve reasonable sample size.

The model is simulated for the pre- and post-reform periods, keeping all deep parameters, except the share of non-Ricardian households the same for both periods. Expansion of the financial services is captured by a lower value of the share of liquidity-constrained households in the post-reform period. The purpose is to identify one of the key factors which may explain the differences in relative consumption volatility between pre- and post-financial reform periods. The model is simulated for two different values of the share of liquidity-constrained households and compares the simulated business cycle moments with business cycle stylised facts observed in pre- and post-reform India.

The key business cycle moments for per capita output, consumption, and investment at annual frequency are estimated. Output, consumption, and investment are measured by real GDP at factor cost, private consumption expenditure, and gross fixed capital formation for the period 1951–2010. To examine the transition in the business cycle stylised facts, the sample is divided into pre- (1951–91) and post-reform periods (1992–2010). Key business cycle

moments are obtained from the hp-filtered cyclical components of per capita output, consumption, and investment.

The trend in one of the key variables of the present analysis, namely, relative consumption volatility, is depicted in figure 4. The mean of relative consumption volatility shows an increase in the post reform period (figure 4).

The change in business cycle facts for the Indian economy from 1951–2009 are depicted in table 4. Per capita Real GDP has become less volatile in the post-reform period in India. The *level* of volatility is still high and comparable to emerging economies. The absolute per capita consumption volatility, as well as the relative consumption volatility with respect to output, increased in the post-reform period. Per capita investment volatility show a small decline in the post-reform period, while volatility in investment relative to output volatility has increased following reform. Contemporaneous correlation of consumption and investment with output has increased in the post-reform period. No significant persistence in the output and consumption cycle is seen in the pre-reform period. In the post-reform period, output and consumption cycle are observed to have higher persistence. Persistence in the investment cycle rises in the post-reform period.

There has been a sharp increase in access to finance after reforms. The ratio of bank accounts to total population was merely 20% in 1980; it has jumped to above 70% in 2010, except for a period of decline in the trend during 1990–2005. Similarly, bank branches per 100,000 population in 2010 were more than double the value in 1970.

As seen in table 4, relative consumption volatility in India has risen from 0.83 during 1951–91 to 1.04 during 1992–2012. Thus, after improved access to savings instruments and credit, fluctuations in consumption relative to fluctuations in income has increased.

### *Calibration*

Table 5 summarises the benchmark parameter values used in the calibration exercise. The access of households to banking is captured by the number of bank accounts to population. Hence the proxy for  $\lambda$ , that is, the share of liquidity-constrained households is derived from this ratio. The number of bank accounts to population ratios in 1980 and 2010 are used to calibrate the share of liquidity-constrained households in the pre- and post-reform periods. In 1980, 21.4% of the population had access to banking. Thus the share of households without access to finance, that is,  $\lambda$ , is set to 0.786 in the pre-reform period. In 2010, 66.9% of the population had access to banking services. The value of  $\lambda$  is thus set to  $1 - 0.669 = 0.331$  in the post-reform period.

Some of the other parameter values are chosen based on the existing literature. A period is a year. The share of labour  $\alpha$  for India is 0.7 as in Verma (2008), while the rate of depreciation is 5% as in Virmani (2004).

Next, the annual discount rate is calibrated using annual data of real interest rates for India sourced from the World Bank. The real interest rate series reported in this database is the lending interest rate adjusted for inflation as measured by the GDP deflator. The trend real interest rate is estimated using the Hodrick-Prescott filter. The average value of the trend real interest rate during the sample period of 1980-2012 is  $\bar{R} = 6.16\%$ . The Euler equation in steady state becomes  $\mu_g = \beta(1 + \bar{R})$ , where  $\mu_g - 1$  is the average trend growth of productivity process and  $\beta$  is the annual discount factor. The value of  $\mu_g - 1$  is obtained from Kalman filtration of Solow residual series for India.<sup>5</sup> The estimated value of  $\mu_g - 1$  is 2.79%. It then follows from the Euler equation that the annual discount factor for India is

$$\beta = \frac{\mu_g}{1 + \bar{R}} = \frac{1.0279}{1.0616} = 0.968.$$

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<sup>5</sup> The details of the estimation procedure and results are outlined in the Consumption Volatility and Permanent versus Transitory Income Shocks section.

The estimated shock processes in the transitory and the growth rate of permanent components of Solow residual for India are sourced from table 3. The parameter for capital adjustment cost  $\phi$  is set to 2.82 from Aguiar and Gopinath (2007).

#### *Effect of Financial Development on Relative Consumption Volatility*

The model predicts that a decline in the share of liquidity-constrained households in the population would allow more people to respond to permanent income shocks. They can increase current consumption more than the rise in current income. This is predicted to result in a rise in the relative consumption volatility.

Main findings are the following. The relative consumption volatility shows a rise in the post-reform period (table 6). This result supports the key prediction of the model. Since financial development allows more people to access savings instruments, when households perceive a permanent income shock which raises both current and future income, more people can respond to the shock by reducing current savings and raising current consumption more than the rise in current income. As a result of financial development, the volatility of consumption relative to volatility of output rises.

This model also replicates the pattern of changes in absolute consumption volatility successfully. The model also captures a decline in the absolute output volatility in the post-reform period as observed in the data. However, in terms of magnitude, the change in the output volatility is not substantial. With financial inclusion, more people can save, and, hence, investment volatility declines. The model shows a fall in the absolute volatility in investment in the post-reform period, as observed empirically. However, unlike the trend shown in the data, the simulated relative investment volatility declines in the post-reform period.

Next, the simulated correlation of consumption and investment cycles with

the output cycle and their persistence with the empirical counterparts are compared in (table 7). The model shows a rise in the correlation of investment with output, as in the data. However, the magnitude of the rise is small compared to the trend shown by the data. The simulated correlation of consumption cycle with the output cycle shows a marginal decline after reform.

The pattern of model simulated persistence in output and consumption cycles matches broadly with the pattern observed in the data. However, the performance of the model is not satisfactory in terms of matching the persistence in the investment cycle. Finally, the model is found to replicate the cyclical pattern in output, consumption, and investment fairly well (figure 5).

#### *Sensitivity to the Measure of Financial Development*

In the above analysis, the financial development is measured by the share of the population with bank accounts. As a robustness check, another measure of financial development, namely, the bank deposit to GDP ratio is used to obtain the fraction of liquidity-constrained households in the economy. By this measure,  $\lambda$  is 0.687 in the pre-reform period. The value of  $\lambda$  in the post-reform period is 0.305.

The key moments from the business cycle model for the pre- and post-reform periods based on this alternative measure of  $\lambda$  are similar to those of the benchmark model (table 8 and 9).

#### FINANCIAL DEVELOPMENT, PERMANENT INCOME SHOCK, AND RELATIVE CONSUMPTION VOLATILITY: IN A SMALL OPEN ECONOMY

Along with domestic financial deepening, opening up of the capital account, or financial liberalisation, has been a major component of the spectrum of reforms in emerging economies in the last two decades. This section explores the implications of financial deepening for the aggregate consumption fluctuations in an open economy framework.

It is assumed that financial transactions by Ricardian households take place

through an internationally traded, one-period, risk-free bond as in Aguiar and Gopinath (2007). The budget constraint of the Ricardian households is modified for the open economy framework as

$$C_t^R + I_t^R + B_t^R - \frac{B_{t+1}^R}{1+R_t} = R_t^K K_t^R + W_t. \quad (21)$$

Here, the level of debt due in period  $t$  held by a Ricardian household is denoted by  $B_t^R$  and  $R_t$  is the time  $t$  interest rate payable for the debt due in period  $t + 1$ . The economy-wide return to physical capital and wage rate are given by  $R_t^K$  and  $W_t$ , respectively. Access to international financial markets is assumed to be imperfect. The interest rate is subject to a premium associated to the riskiness of investing in emerging economies. This premium depends on the level of outstanding debt, taking the form used in Schmitt-Grohe and Uribe (2003),

$$R_t = R^* + \psi \left( e^{\frac{B_{t+1} - \bar{b}}{\Gamma_t}} - 1 \right). \quad (22)$$

Here the variable  $R^*$  is the world interest rate exogenously given to the small open home country. The variable  $\bar{b}$  denotes the steady state level of total debt, and  $\psi$  ( $\psi > 0$ ) is the elasticity of interest rate to changes in the indebtedness of the economy. The total debt of the economy  $B_t$  is exogenously given to the representative agent who does not internalise the premium payable on the foreign interest rate determined by the indebtedness of the economy. However, in equilibrium, total foreign debt of the economy coincides with the amount of debt acquired by all the representative agents of the Ricardian type. Given the fraction of Ricardian households in the economy equal to  $1 - \lambda$ , the total debt in the economy amounts to  $B_t = (1 - \lambda)B_t^R$ , while the long run total debt is  $\bar{b} = (1 - \lambda)\bar{b}^R$ .

The resource constraint equation for the open economy is modified as follows:

$$C_t + I_t + TB_t = Y_t, \quad (23)$$

where the trade balance  $TB_t$  is financed by the net flows of capital,

$$TB_t = B_t - \frac{B_{t+1}}{1 + R_t}. \quad (24)$$

In an economy which is open on both trade and financial fronts, imports and total domestic output net of exports is allocated between total consumption and investment, where the difference between exports and imports are balanced by the financial flows as indicated by equations (23) and (24). The rest of the framework, such as the optimisation problem of the Ricardian and the liquidity-constrained households, firm's profit maximisation behaviour, and the permanent and transitory shock structures remain similar, as in the closed economy framework. By normalising the variables with respect to the permanent component of productivity at period  $t-1$ , the detrended system of equations are obtained. The Supplemental Appendix S3 contains the detrended system of equations pertaining to the open economy.

### *Calibration to Indian Data*

In order to calibrate the open economy, value of the interest rate elasticity of indebtedness is set to 0.001, as in Aguiar and Gopinath (2007). The steady state level of debt to GDP ratios for the pre- and post-reform periods are set to the average values of the external debt to GDP ratios in 1971–91 and 1992–2012, respectively. The respective values are 16.30% and 21.39%.<sup>6</sup>

The value of the risk-free world interest rate is set to satisfy the condition that  $\beta(1 + R^*) = \mu_g$ , where  $\mu_g - 1$  is the mean growth rate of the permanent component of TFP. The value of this parameter is set to 2.79% based on the estimated permanent component of TFP as outlined in the Consumption Volatility

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<sup>6</sup> The annual series of external debt are sourced from WDI. The data spans from 1971–2012 and are in current US\$. The GDP data, also in current US\$, are sourced from WDI.

and Permanent versus Transitory Income Shocks section. The rest of the parameter values remain the same, as in the closed economy case.

Data show, in addition to business cycle stylised facts with respect to the key macroeconomic indicators in India (table 4), more than one-and-a-half times increase in the mean net exports to GDP ratio from pre- to the post-reform period in India (table 10). The business cycle volatilities, both absolute and relative, in trade balance to GDP ratio have also increased in the post-reform period. The trade balance to GDP ratio has become strongly counter cyclical after the reform, from being merely acyclical in the pre-reform period (table 10).

The empirical and simulated business cycle moments for the open economy in the pre- and post-reform periods are compared in tables 11 and 12. The open economy version of the model is able to replicate most of the patterns in the changes in stylised facts from the pre- to post-reform periods in India. As observed in the data, the model-simulated absolute volatilities in consumption and trade balance to GDP ratio have increased in the post-reform period, while that of investment has decreased. However, unlike in the data, the volatility of output in the model shows a rise in the post-reform period and the absolute volatility in the trade balance to GDP ratio exceeds output volatility.

So far as the relative volatilities are concerned, volatilities in consumption and trade balance to GDP ratio, relative to output volatility rise, reflecting trends observed in the data. However, unlike the pattern observed empirically, the relative volatility of investment falls. The relative volatility of investment resembles the pattern observed in the closed economy framework.

The model-simulated correlation of investment with output increases after the reform, although the model is not able to capture the sharp rise in the correlation as observed in the data. The data shows that the correlation of trade balance to GDP ratio turns from acyclical to strongly counter-cyclical. Although

the model shows that trade balance to GDP ratio has a negative correlation with output, and the magnitude of the correlation increases in the post-reform period, but it does not become strongly countercyclical after the reform. The correlation of consumption with output declines, whereas it increases in the data after the reform.

### *Discussion of the Results*

The open economy framework, when calibrated to Indian data, supports the main prediction of rising relative consumption volatility with financial inclusion. Broadly, the model-simulated moments show similar patterns observed in the closed economic framework, except for a marginal rise in the output volatility in the post reform period.

One plausible reason for the open economy setup to show similar trends in the volatility and correlation of the key macroeconomic indicators, as in the closed economy scenario, is that financial deepening, in the present model, works through the household channel. Under strong permanent income shock, relative to transitory income fluctuations, Ricardian households behave in a similar manner in both closed and open economy setups. However, the extent of fluctuations is higher in an open economy. In response to permanent income shock, in an open economy, households can even raise current consumption more by using funds borrowed against future income. Hence fluctuation in consumption is even higher than the closed economy scenario. Financial inclusion, in this setup results in larger fluctuations in aggregate consumption. A sharp rise in consumption volatility with a relatively smaller decline in investment volatility causes a marginal rise in post-reform output fluctuations. Hence, the open and closed economy setups show qualitatively similar results.

In this open economy framework, consumers transact an internationally traded bond, which is the source of capital flows in the economy. A bulk of literature has explored macroeconomic effects of the interaction between financial

openness and domestic financial development through firm borrowing channel (Aghion et al. 2004, 2010). Incorporating borrowing by firm in the model may provide an additional channel for the interaction between financial development and financial liberalisation to affect output and investment. However, in spite of the fact that India started liberalising capital account in 1991, the pace and the extent of easing restrictions on capital flows remained low compared to other emerging economies. The access to foreign capital by Indian households and firms are still limited due to a wide array of capital control measures existing in the country. The de jure measure of capital account openness based on the Chinn-Ito index shows that India is relatively closed compared to other large emerging economies (Patnaik and Shah 2012) (see figure 6). Households in India are not allowed to borrow abroad. There are a number of restrictions on foreign borrowing by firms, and both macro and firm level data indicate low exposure of Indian firms to foreign capital.<sup>7</sup> Given the low level of access to foreign capital by Indian households and firms, an open economy setup through the financial channel may not be appropriate to replicate the post-reform business cycle stylised facts in India.

India liberalised current account at a faster pace than capital account.

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<sup>7</sup> Along with domestic financial deepening, opening up of the capital account, or financial liberalization, has been a major component of reforms in India since 1991. However, the access to foreign capital by Indian households and firms have remained limited. Households and banks in India are not allowed to borrow abroad. As far as borrowing by firms are concerned, Indian firms access foreign capital through two channels to leverage their operations. These are Foreign Direct Investment (FDI) and foreign borrowings. FDI in India (net inflows) has grown from USD 0.59 billion in 1993–94 to USD 30.76 billion in 2013–14 (Economic Outlook, Centre for Monitoring Indian Economy). However, the net FDI inflows in India accounts for only 1.78% of GDP in 2013–14. The share of net FDI inflows in India in total investment amounts to 5.24% in 2013–14. To compare with other emerging economies, for instance, net FDI inflows in Brazil in 2013 has been USD 80.84 billion, which is more than double the FDI inflows in India, while the net FDI inflows in China in 2013 has been USD 347.85, which is more than eleven times larger the FDI flows in India (World Development Indicators). Looking deep into the firm-level database, only 623 firms are found to have foreign promoter (ownership) in a base of 26,725 companies at the end of 31st March, 2014 (Prowess, Centre for Monitoring Indian Economy). India holds stock under foreign borrowings of USD 53.92 billion in 2012–13 and 2013–14. The net inflow of foreign borrowings has accounted for only 0.63% of GDP in 2013–14. Again in a sample of 26,725 firms in the Prowess database, only a total of 642 companies are found to have had foreign borrowings over the years, while only 464 companies have executed for the financial year 2013–14.

Explicitly modelling the current account incorporating home and foreign goods in consumption and investment, as in Mendoza (1995) and Kose and Yi (2006) would provide an additional channel of trade liberalisation to affect macroeconomic volatility and cyclicalities of various indicators with output.

#### CONCLUSION

Emerging economies have been seen to witness an increase in consumption volatility relative to output volatility after financial development. This behaviour appears puzzling since traditional models and evidence from advanced economies suggest that consumption should become smoother with increase in the access to financial services.

A distinguishing feature of developing economies is that a large share of the population does not have access to finance. In the last two decades, these economies have experienced reforms in the financial sector giving greater access to financial services for households and firms. Yet, these economies experienced an increase in consumption volatility relative to output volatility in the post-reform period. This paper addresses this empirical puzzle. This puzzle can be explained in a model featuring credit constraints and shocks to trend growth of productivity. The model predicts that relative consumption volatility will rise when more consumers can smooth consumption.

The model, when simulated for India before and after an increase in financial development, broadly replicates the rise in relative consumption volatility, as observed in the data. Most of the other empirical regularities observed in the data are also replicated by this model.

The benchmark model represents a closed economy, and the concept of financial development is limited to household's access to financial services. The model assumes that the household sector is the sole channel for the financial development to work. This is one plausible reason for the model's weak

performance in replicating the business cycle patterns with respect to investment. By including credit-constrained firms in this framework, one can examine the role of financial development further. Extending the model with borrowings by firms will help in understanding how increase in households' access to finance affects consumption-smoothing behaviour when production and demand for resources are subject to firm's access to finance.

Finally, the open economy framework, following Aguiar and Gopinath (2007), assumes that consumers transact an internationally traded bond, which is the source of capital flows in the economy. A bulk of literature has explored macroeconomic effects of the interaction between financial openness and domestic financial development through the firm borrowing channel (Aghion et al. 2004, 2010). However, a wide array of capital control measures existing in India (Patnaik and Shah 2012) restricts access of Indian households and firms to foreign capital. Again, India liberalised current accounts at a faster pace than capital accounts. Hence an open economy framework, capturing trade liberalisation following Mendoza (1995) and Kose and Yi (2006), may help in improving the fit of the model in the open economy framework.

Further, differentiating between agricultural and nonagricultural goods in the consumption basket may help to capture the effects of structural shifts away from agriculture to nonagriculture on the post-reform stylised facts.

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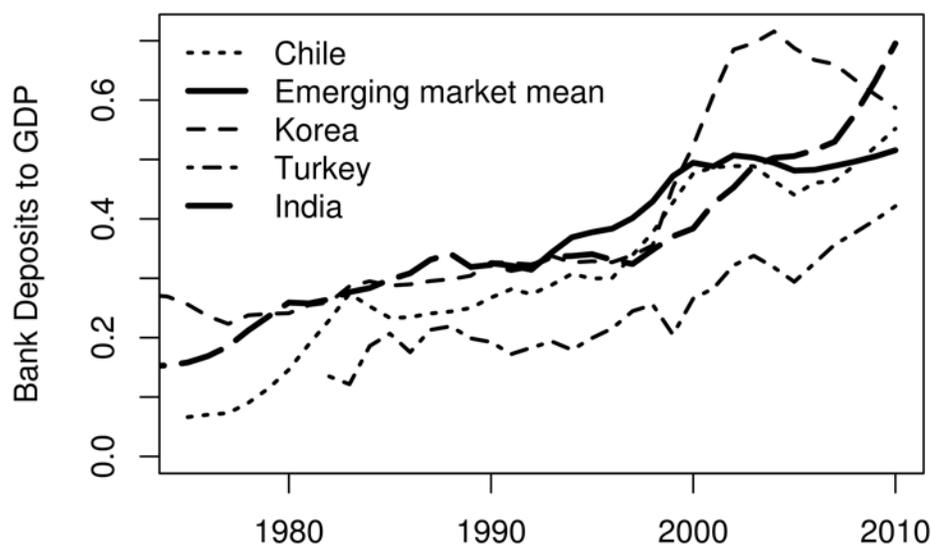
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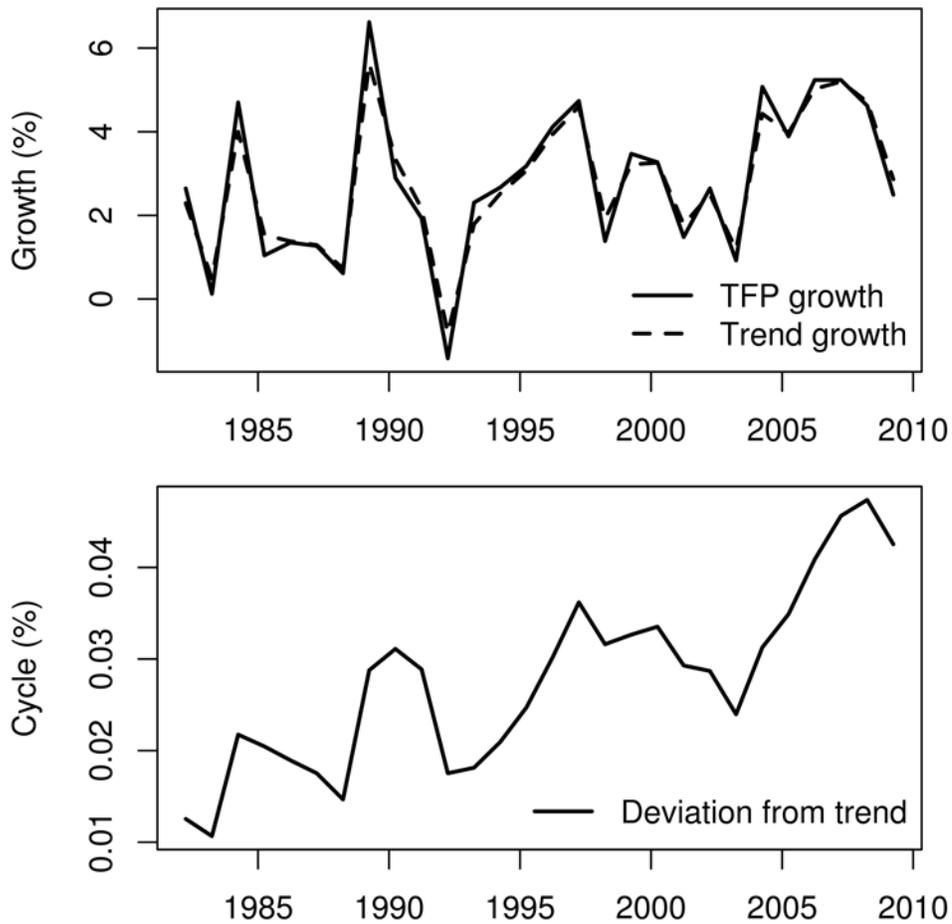
**Figure 1** Financial Development.



This figure shows the average deposits to GDP ratio of a set of emerging economies and a few individual countries in the set. The set of emerging economies consists of Chile, Columbia, Mexico, Peru, Indonesia, Malaysia, Philippines, Korea, Taiwan, Thailand, Turkey, Poland, Hungary, India, and South Africa.

*Source:* International Financial Statistics, IMF.

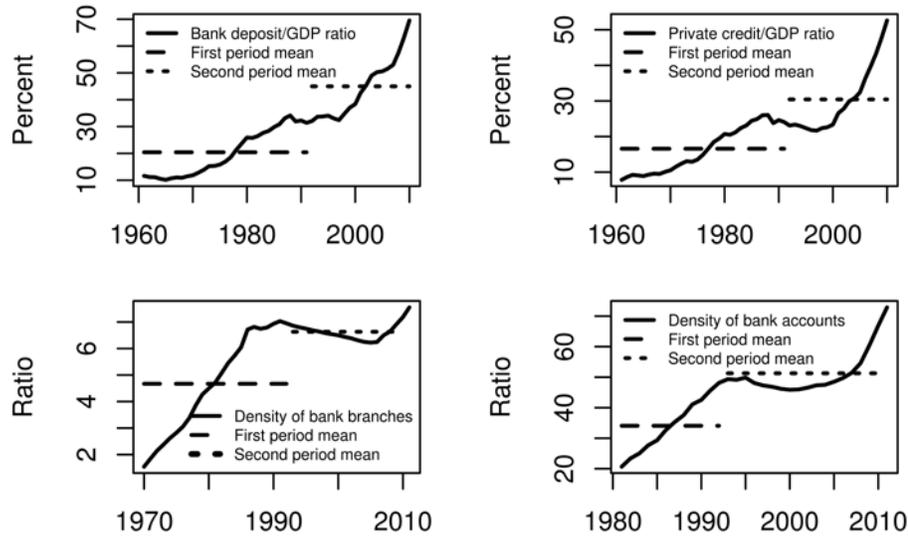
**Figure 2.** Permanent and Transitory Movements in Solow Residual for India



This figure depicts actual and the trend growth rates vis-à-vis the transitory component of the Solow residual for India. The figure shows that the trend growth rate of the Solow residual is characterised by significant fluctuations.

*Source:* Authors' analysis outlined in the Consumption Volatility and Permanent versus Transitory Income Shocks section.

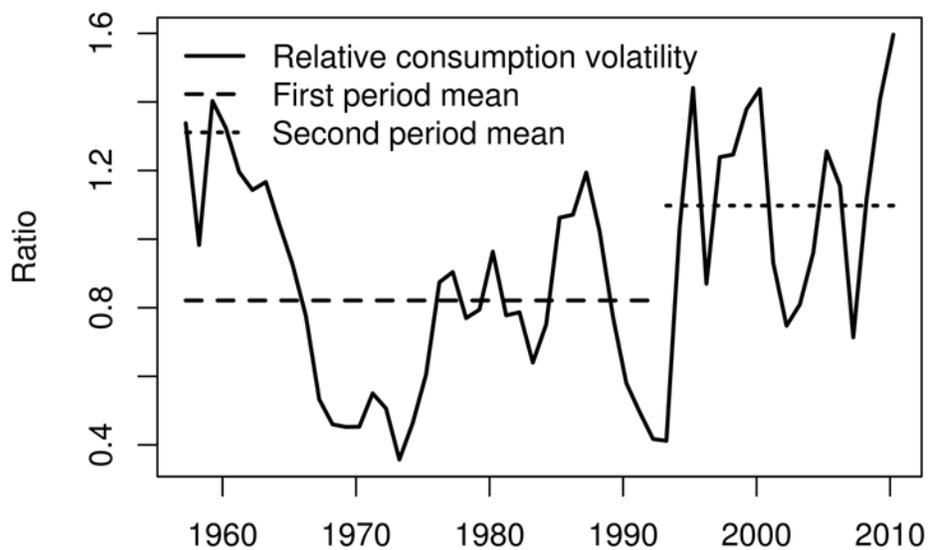
**Figure 3** Financial Development in India



This figure shows the behaviour of some financial development indicators in India. The upper two panels depict bank deposit to GDP ratio and the private credit to GDP ratio. The left lower panel shows number of bank branches per 100,000 people. The right lower panel shows number of bank accounts per 100,000 people. The density of bank accounts and that of bank branches, bank deposit to GDP ratio, and private credit to GDP are all seen to rise. The dashed lines show the mean values before and after financial reforms.

*Source:* International Financial Statistics, IMF, World Development Indicators, World Bank, and Reserve Bank of India.

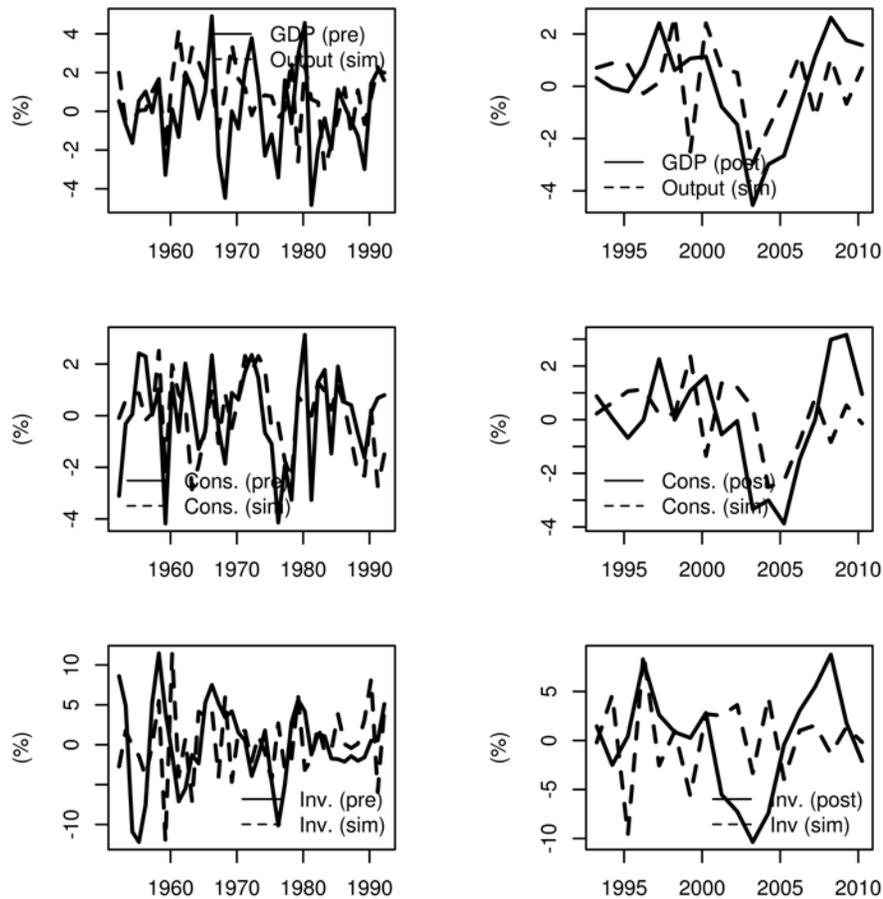
**Figure 4** Trend in Relative Consumption Volatility



This figure shows the five year rolling relative consumption volatility in India during 1956–2009.

*Source:* National Accounts Statistics, India, authors' estimates.

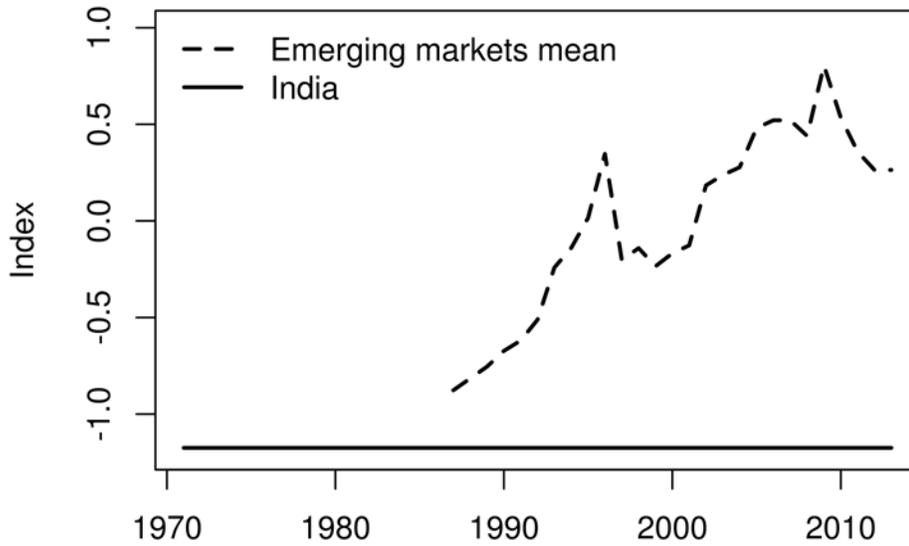
**Figure 5.** Actual and Simulated Cycles



This figure compares cyclical movements in per capita GDP, consumption expenditure and investment with simulated output, and consumption and investment cycles for the pre- and post-reform periods. The left panel shows key macroeconomic cycles in the pre-reform period, whereas the right panel depicts post-reform cyclical fluctuations in the macroeconomic indicators.

*Source:* Authors' estimates outlined in the Case Study section

**Figure 6:** De Jure Financial Integration: Chinn-Ito Measure



This figure depicts an index of capital account openness based on the “Annual Report on Exchange Arrangements and Exchange Restrictions” of the IMF (Chinn and Ito 2008). This figure compares the index of capital account openness for India with the emerging economy mean. The set of emerging economies includes countries in table 1 of the paper, except Taiwan.

*Source:* Chinn and Ito (2008)

**Table 1** Relative Consumption Volatility: Selected Emerging Economies

This table shows the reform date and the volatility of consumption relative to that of output in the pre- and post-reform period for a set of emerging economies.

Region & reform date	Relative consumption volatility		
	Pre-reform	Post-reform	Change
Latin America: 1990			
Chile	1.10	1.26	↑
Colombia	0.97	0.85	↓
Mexico	0.94	1.45	↑
Peru	1.09	1.72	↑
East Asia: 1996			
Indonesia	2.45	1.01	↓
Malaysia	1.36	1.52	↑
Philippines	0.73	1.06	↑
Korea	0.93	1.69	↑
Taiwan	1.84	0.80	↓
Thailand	0.88	1.00	↑
East Europe: 1990			
Turkey	1.07	1.09	↑
Poland	0.92	1.45	↑
Hungary	1.01	1.50	↑
South Asia			
India: 1992	0.83	1.23	↑
Africa			

South Africa: 1994	1.42	1.40	↓
Mean	1.15	1.29	↑
Std. dev.	0.44	0.30	

*Source:* Datastream, author's calculations

### **Table 2** Access to Finance

This table depicts the density of commercial bank branches and depositors with commercial banks in emerging economies in the beginning and in the end of the decade of 2000–10.

Country	Commercial bank branches per 100,000 adults		Depositors with commercial banks per 1,000 adults	
	2004	2010	2004/2005/2006	2010
Chile	13	18	1410	2134
Colombia				
Mexico	11	15	..	1205
Peru	4	50	340	436
Indonesia	5	8		
Malaysia	13	..	1792	..
Philippines	8	8	370	488
Korea	17	19	4279	4522
Taiwan				
Thailand	8	11	984	1120

Turkey	13	..	1362	..
Poland	37	46		
Hungary	14	17	798	1072
India	10	11	637	747
South Africa	5	10	384	978

*Source:* Financial Inclusion, World Development Indicators

**Table 3** Comparing cross country technology shock processes

This table depicts cross country relative consumption volatility vis-à-vis the magnitude of shocks to trend growth documented from literature.

	AG, 2007				NT, 2011						India (1980 – 2008)
	Mexico		Canada		Developed		Emerging		SSA		
	Dat a	Mod el	Dat a	Mod el	Dat a	Mod el	Dat a	Mod el	Dat a	Mod el	
$\sigma_y$	2.4 0	2.13– 2.40	1.5 5	1.24– 1.55	2.2 5	2.27	3.7 1	3.83	4.2 5	5.16	1.84
$\sigma_c$	3.0 2	3.02– 3.27	1.1 5	0.94– 1.41	2.3 3	2.16	4.5 4	3.96	7.4 9	5.43	1.81
$\sigma_c/\sigma_y$	1.2 6	1.10– 1.33	0.7 4	0.74– 0.91	1.0 4	0.95	1.2 2	1.03	1.7 6	1.05	0.99
$\rho_g$		0.00– 0.11		0.03– 0.29		-0.13		-0.11		0.05	0.27

$\sigma_g$		2.13– 3.06		0.47– 1.20		2.89		5.33		6.20	1.59
$\rho_a$		0.95		0.97							0.84
$\sigma_a$		0.17– 0.54		0.63– 0.78		0.68		0.73		0.58	0.32

Source: Aguiar and Gopinath (2007), Naoussi and Tripier (2013), authors' analysis outlined in the Consumption Volatility and Permanent versus Transitory Income Shocks section

**Table 4** Business Cycle Stylised Facts for the Indian Economy in the Pre- and Post-Reform Period

This table reports the changes in business cycle facts for the Indian economy from the pre-reform to the post-reform periods. The span of the analysis is 1951–2009.

	Pre-reform period (1951–91)				Post-reform period (1992–2009)			
	Std. dev.	Rel. std. dev.	Cont. cor.	First ord. auto corr.	Std. dev.	Rel. std. dev.	Cont. cor.	First ord. auto corr.
Real GDP	2.25	1.00	1.00	0.056	1.93	1.00	1.00	0.714
Pvt. Cons.	1.86	0.83	0.70	0.038	1.99	1.04	0.92	0.605
Investment	5.26	2.34	0.19	0.510	5.18	2.69	0.76	0.607

Source: National Accounts Statistics, Labour Bureau, authors' estimates outlined in the Case Study section

**Table 5** Benchmark Parameter Values

This table summarises the parameter values used for the calibration exercise. Rate of depreciation, mean trend growth rate, and volatilities of trend growth rate and transitory component of TFP are in percentage (%).

Parameters		Values
Discount factor	$\beta$	0.968
Rate of Depreciation	$\delta$	5.000
Share of labour	$\alpha$	0.700
Adjustment cost parameter	$\phi$	2.820
Mean trend growth rate of labour productivity	$\mu_g - 1$	2.790
Persistence in transitory component of technology	$\rho_c$	0.760
Volatility in transitory component of technology	$\sigma_a$	0.320
Persistence in growth of permanent component of technology	$\rho_g$	0.266
Volatility of shock to permanent component of technology	$\sigma_g$	1.590

*Source:* Virmani (2004), Verma (2008), Aguiar and Gopinath (2007), and authors' estimates outlined in the Consumption Volatility and Permanent versus Transitory Income Shocks section and in the Case Study section

**Table 6 Business Cycle Volatilities from the Simulated Model**

This table presents absolute and relative business cycle volatilities from the simulated model for the pre- and post-reform periods. The absolute standard deviation numbers are in percentage (%). The relative standard deviations are in ratio.

	Std. dev.			Rel. std. dev.	
	Y	C	I	C	I
<b>Data</b>					
Pre-reform	2.25	1.86	5.26	0.83	2.34
Post-reform	1.93	1.99	5.18	1.04	2.69
<b>Model</b>					
Pre-reform	1.92	1.97	4.46	1.03	2.32
Post-reform	1.91	2.16	3.53	1.13	1.85

*Source:* Authors' analysis outlined in the Case Study section

**Table 7** Business Cycle Correlation and Persistence from the Simulated Model

This table presents respective contemporaneous correlations of consumption and investment cycles with output cycle and the persistence in output, consumption, and investment cycles. These business cycle moments from the simulated model are reported for the pre- and post-reform periods.

	Correlation		Auto-correlation		
	C	I	Y	C	I
Data					
Pre-reform	0.70	0.19	0.056	0.038	0.510
Post-reform	0.92	0.76	0.714	0.605	0.607
Model					
Pre-reform	0.99	0.22	0.524	0.617	-0.142
Post-reform	0.97	0.24	0.534	0.747	-0.116

*Source:* Authors' analysis outlined in the Case Study section

**Table 8** Sensitivity Analysis with Respect to the Financial Development  
Parameter

This table presents business cycle moments from the simulated model for the pre- and post-reform period using an alternative measure of  $\lambda$ . The measure used in this analysis is based on the deposit to GDP ratio. The absolute standard deviation numbers are in percentage (%). The relative standard deviations are in ratio. The patterns of transition of business cycle moments broadly resemble the benchmark analysis.

	Std. dev.		Rel. std. dev.		
	Y	C	I	C	I
Data					
Pre-reform	2.25	1.86	5.26	0.83	2.34
Post-reform	1.93	1.99	5.18	1.04	2.69
Model					
Pre-reform	1.92	2.00	4.11	1.04	2.14
Post-reform	1.91	2.18	3.99	1.14	2.09

*Source:* Authors' analysis outlined in the Case Study section

**Table 9** Sensitivity Analysis with Respect to the Financial Development  
Parameter

This table shows that business cycle moments from the simulated model for the pre- and post-reform period using the alternative measure of  $\lambda$  based on deposit to GDP ratio. The patterns of transition of the moments broadly resemble the patterns from benchmark analysis.

	Correlation		Auto-correlation		
	C	I	Y	C	I
Data					
Pre-reform	0.70	0.19	0.056	0.038	0.510
Post-reform	0.92	0.76	0.714	0.605	0.607
Model					
Pre-reform	0.99	0.23	0.527	0.651	-0.133
Post-reform	0.96	0.24	0.534	0.753	-0.115

*Source:* Authors' analysis outlined in the Case Study section

**Table 10** Stylised Facts on Trade Balance to GDP Ratio in India in the Pre- and Post-Reform Period

This table presents business cycle moments and the average value of the trade balance to GDP ratio for the pre- and post-reform periods.

	Pre-reform period (1951–1991)	Post-reform period (1992–2009)
Mean	1.99	3.48
Std. dev.	0.90	1.16
Rel. std.dev.	0.40	0.60
Cont. cor.	0.25	-0.69
First ord. auto. corr.	0.246	0.504

*Source:* National Accounts Statistics, authors' estimates outlined in the Financial Development, Permanent Income Shock, and Relative Consumption Volatility in a Small Open Economy section

**Table 11** Simulated Business Cycle Volatilities from the Open Economy Model

This table compares absolute and relative business cycle volatilities from the simulated model for the pre- and post-reform period with the pattern observed in the data. The absolute volatilities are in percentage (%). The relative standard deviations are in percentage.

	Std. dev.				Rel. std. dev.		
	Y	C	I	$\frac{TB}{Y}$	C	I	$\frac{TB}{Y}$
Data							
Pre-reform	2.17	1.86	5.26	0.92	0.86	2.42	0.42
Post-reform	1.94	1.99	5.18	1.24	1.03	2.67	0.64
Model							
Pre-reform	1.48	2.14	6.63	2.75	1.44	4.48	1.86
Post-reform	1.51	2.94	6.43	3.46	1.95	4.26	2.29

*Source:* Authors' analysis outlined in the Financial Development, Permanent Income Shock, and Relative Consumption Volatility in a Small Open Economy section

**Table 12** Simulated Business Cycle Correlation and Persistence from the  
Open Economy Model

This table compares business cycle correlation of various macroeconomic indicators with output cycle and persistence from the simulated model for the pre- and post-reform periods with the patterns observed in the data.

	Correlation			Auto-correlation			
	C	I	$\frac{TB}{Y}$	Y	C	I	$\frac{TB}{Y}$
Data							
Pre-reform	0.71	0.19	0.25	0.055	0.038	0.510	0.245
Post-reform	0.83	0.76	-0.59	0.701	0.605	0.607	0.502
Model							
Pre-reform	0.80	0.20	-0.15	0.354	0.633	0.806	0.793
Post-reform	0.72	0.21	-0.21	0.376	0.751	0.799	0.775

Source: Authors' analysis outlined in the Financial Development, Permanent Income Shock, and Relative Consumption Volatility in a Small Open Economy section

Supplemental appendixes for the article  
“Financial inclusion, productivity shocks and  
consumption volatility in emerging economies”

Rudrani Bhattacharya and Ila Patnaik

# S1 Appendix S1

**Table S1.1** Data span for GDP and consumption expenditure: Emerging economies

Region & reform date	Span of data		Source of reform date
	Start date	End date	
Latin America: 1990			Singh, Belaisch, Collins, Masi, Krieger, Meredith, and Rennhack (2005)
Chile	1974	2010	
Colombia	1968	2010	
Mexico	1978	2011	
Peru	1989	2011	
East Asia: 1996			Kim, Kose and Plummer (2003)
Indonesia	1978	2011	
Malaysia	1970	2011	
Philippines	1958	2011	
Korea	1953	2010	
Taiwan	1981	2011	
Thailand	1950	2011	
East Europe: 1990			Alp, Baskaya, Kilinc, and Yuksel (2012), Thorne (1993)
Turkey	1989	2010	
Poland	1981	2011	
Hungary	1971	2011	
South Asia			
India: 1992	1951	2012	Ghate, Pandey and Patnaik (2013)
Africa			
South Africa: 1994	1950	2011	Habib and Padayachee (2000)

Given the availability of data for Peru, comparison of relative consumption volatility before and after 2000 is made.

## S2 Appendix S2

### S2.I Solution of the log-linearised system of equations using method of undetermined coefficients

Log-linearisation of the system of equations (19) around the steady state, and substituting the log-linearised expression of  $\Omega_t$  in that of the Euler equation yields,

$$\begin{aligned}
 \tilde{c}_t^R &= \left( \frac{1 - \lambda\alpha}{1 - \lambda} \right) \frac{y^*}{c^{R*}} + \left[ \left( \frac{1 - \lambda\alpha}{1 - \lambda} \right) \frac{\mu_g k^*}{\beta c^{R*}} - \frac{\lambda(1 - \alpha)(1 - \delta) k^*}{1 - \lambda} \frac{1}{c^{R*}} \right] \tilde{k}_t^R \\
 &\quad - \frac{\mu_g k^{R*}}{c^{R*}} \tilde{k}_{t+1}^R - \frac{\mu_g k^{R*}}{c^{R*}} \tilde{g}_t, \\
 0 &= E_{t-1} \left[ \tilde{c}_{t+1}^R - \tilde{c}_t^R + A(a_t - \alpha \tilde{k}_t^R + \alpha \tilde{g}_t) \right]; \quad A = 1 - \frac{\beta(1 - \delta)}{\mu_g}, \\
 a_t &= \rho_a a_{t-1} + \epsilon_t^a, \\
 \tilde{g}_t &= \rho_g \tilde{g}_{t-1} + \epsilon_t^g; \quad \tilde{g}_t = \ln \left( \frac{g_t}{\mu_g} \right),
 \end{aligned} \tag{S2.1}$$

where the cyclical component of a variable  $x_t$  is defined as  $\tilde{x}_t = \ln x_t - \ln x^*$  and  $x^*$  denotes the steady state value of  $x_t$ .<sup>1</sup> The steady state growth rate of labour productivity is the long term average trend growth rate  $\mu_g$ . The last two equations in the system of equations (S2.1) yield volatility of transitory and permanent income shocks as  $\sigma_a^2 = \frac{\sigma_{\epsilon_a^2}}{1 - \rho_a^2}$  and  $\sigma_g^2 = \frac{\sigma_{\epsilon_g^2}}{1 - \rho_g^2}$ .

---

<sup>1</sup>To log-linearise the equations of the model, the method of approximation  $x_t = e^{\tilde{x}_t} x^* \approx (1 + \tilde{x}_t) x^*$  is used.

The solution of the system of equations (S2.1) takes the form

$$\begin{aligned}\tilde{k}_{t+1}^R &= a_1 \tilde{k}_t^R + b_1 a_t + d_1 \tilde{g}_t \\ \tilde{c}_t^R &= a_2 \tilde{k}_t^R + b_2 a_t + d_2 \tilde{g}_t.\end{aligned}\tag{S2.2}$$

The unknown parameters  $(a_1, b_1, d_1, a_2, b_2, d_2)$  are functions of  $(\beta, \alpha, \delta, \lambda, \mu_g)$  and are solved using the method of undetermined coefficients. The solution (S2.2) of the dynamic system indicates that each endogenous variable in time  $t$  is a linear function of the state variables  $(k_t^R, a_t, g_t)$ . For the system to satisfy transversality condition, i.e., convergence of the system to the steady state over time,  $\tilde{k}_t^R$  must converge to zero following a shock. That is,  $a_1$  must satisfy the condition  $a_1 < 1$ .

Substituting solution (S2.2) in the first equation in the system of equations (S2.1), the following is obtained,

$$\begin{aligned}a_2 \tilde{k}_t^R + b_2 a_t + d_2 \tilde{g}_t &= \left( \frac{1 - \lambda \alpha}{1 - \lambda} \right) \frac{y^*}{c^{R*}} + \left[ \left( \frac{1 - \lambda \alpha}{1 - \lambda} \right) \frac{\mu_g k^*}{\beta c^{R*}} - \frac{\lambda(1 - \alpha)(1 - \delta)}{1 - \lambda} \frac{k^*}{c^{R*}} \right] \tilde{k}_t^R \\ &\quad - \frac{\mu_g k^{R*}}{c^{R*}} [a_1 \tilde{k}_t^R + b_1 a_t + d_1 \tilde{g}_t] - \frac{\mu_g k^{R*}}{c^{R*}} \tilde{g}_t\end{aligned}$$

Re-arranging the terms yields

$$a_2 = \left[ \left( \frac{1 - \lambda\alpha}{1 - \lambda} \right) \frac{\mu_g k^{R*}}{\beta c^{R*}} - \frac{\lambda(1 - \delta)(1 - \alpha) k^{R*}}{1 - \lambda} \frac{1}{c^{R*}} - \frac{\mu_g k^{R*}}{c^{R*}} a_1 \right] \quad (\text{S2.3})$$

$$b_2 = \left( \frac{1 - \lambda\alpha}{1 - \lambda} \right) \frac{y^*}{c^{R*}} - \frac{\mu_g k^{R*}}{c^{R*}} b_1 \quad (\text{S2.4})$$

$$d_2 = - \left[ \frac{\mu_g k^{R*}}{c^{R*}} d_1 + \frac{\mu_g k^{R*}}{c^{R*}} \right] \quad (\text{S2.5})$$

where the steady state value of consumption of a Ricardian household, and the steady state value of the output are respectively  $c^{R*} = \left( \frac{1 - \lambda\alpha}{1 - \lambda} \right) (1 - \lambda)^{(1-\alpha)} (k^{R*})^{1-\alpha} \mu_g^\alpha - (\mu_g - 1 + \delta) k^{R*}$  and  $y^* = (1 - \lambda)^{(1-\alpha)} (k^{R*})^{1-\alpha} \mu_g^\alpha$ , given the steady state value of capital stock of a Ricardian household is,

$$k^{R*} = \left[ \frac{(1 - \alpha)(1 - \lambda)^{1-\alpha} \mu_g^\alpha}{\frac{\mu_g}{\beta} - (1 - \delta)} \right]^{1/\alpha}.$$

The steady state expression of stock of capital of a Ricardian household is derived from the Euler equation and the expression of gross return to capital given in the equation system (19) assuming that in the steady state, all variables normalised by the labour productivity of the previous period remain constant along the steady state, i.e.,  $\tilde{k}_t^R = \tilde{k}_{t+1}^R = k^{R*}$ , and  $\tilde{c}_t^R = \tilde{c}_{t+1}^R = c^{R*}$ . The steady state growth rate of labour productivity is the long-run average trend growth rate  $\mu_g$ . Also, the steady state is free of any transitory movement in the total factor productivity, hence,  $a_t = a_{t+1} = 0$ . Given the value of  $k^{R*}$ , the steady state value of consumption  $c^{R*}$  is derived from the resource constraint equation in (19). It then follows from equations (11), (14), (12)

that the steady state consumption of the liquidity constrained households and the total consumption are respectively  $c^{L*} = \alpha y^*$  and  $c^* = (1 - \lambda)c^{R*} + \lambda c^{L*}$ .

Substituting the solution (S2.2) in the second equation of (S2.1), and making the use of  $E_{t-1}a_t = \rho_a a_{t-1}$  and  $E_{t-1}\tilde{g}_t = \rho_g \tilde{g}_{t-1}$  yields

$$a_2 - a_2 a_1 - A\alpha a_1 = 0 \quad (\text{S2.6})$$

$$b_2(1 - \rho_g) - a_2 b_1 + A\rho_a - A\alpha b_1 = 0 \quad (\text{S2.7})$$

$$d_2(1 - \rho_g) - a_2 d_1 - A\alpha d_1 + A\alpha \rho_g = 0 \quad (\text{S2.8})$$

Again, substituting expression (S2.4) in the expression (S2.8), and rearranging the terms yields a quadratic equation in  $a_1$ ,

$$a_1^2 - \gamma_1 a_1 + \gamma_2 = 0 \quad (\text{S2.9})$$

where

$$\gamma_1 = 1 + \left(\frac{1 - \lambda\alpha}{1 - \lambda}\right) \frac{1}{\beta} - \frac{\lambda(1 - \alpha)(1 - \delta)}{(1 - \lambda)\mu_g} + A\alpha \frac{c^{R*}}{\mu_g k^{R*}}$$

$$\gamma_2 = \left(\frac{1 - \lambda\alpha}{1 - \lambda}\right) \frac{1}{\beta} - \frac{\lambda(1 - \alpha)(1 - \delta)}{(1 - \lambda)\mu_g} \quad (\text{S2.10})$$

$$(\text{S2.11})$$

The solution of the above quadratic equation is

$$a_1 = \frac{\gamma_1}{2} \pm \sqrt{\left(\frac{\gamma_1}{2}\right)^2 - \gamma_2} \quad (\text{S2.12})$$

If there is no friction in the credit market so that the entire population can access financial services and hence smooth consumption, then  $\lambda = 0$ . Then the product of the two roots in expression (S2.12) is  $\gamma_2 = 1/\beta > 1$ , where the value of  $\gamma_2$  is obtained by evaluating expression (S2.11) at  $\lambda = 0$ . Again, as  $\lim_{\lambda \rightarrow 0} \gamma_2 \rightarrow \infty$ . Hence, the product of the two roots as in the expression (S2.12)  $\gamma_2$  is always greater than 1, irrespective of the value of  $\lambda$ . Therefore it follows that the larger one must exceed 1 and only the smaller one can possibly satisfy the convergence condition  $a_1 < 1$ . Hence, the solution of the quadratic equation (S2.9) is

$$\hat{a}_1 = \frac{\gamma_1}{2} - \sqrt{\left(\frac{\gamma_1}{2}\right)^2 - \gamma_2}. \quad (\text{S2.13})$$

Given this solution of  $a_1$ , from equations (S2.4), (S2.5), (S2.6), (S2.7), (S2.8), (S2.9) and making use of the steady state values  $(k^{R*}, c^{R*}, y^*)$ , one can solve for  $(a_2, b_1, b_2, d_1, d_2)$  as

$$\begin{aligned} \hat{a}_2 &= \left[ \left( \frac{1 - \lambda\alpha}{1 - \lambda} \right) \frac{\mu_g k^{R*}}{\beta c^{R*}} - \frac{\lambda(1 - \delta)(1 - \alpha) k^{R*}}{1 - \lambda} \frac{1}{c^{R*}} - \frac{\mu_g k^{R*}}{c^{R*}} \hat{a}_1 \right] \\ \hat{b}_1 &= \frac{(1 - \rho_a) \left( \frac{1 - \lambda\alpha}{1 - \lambda} \right) \frac{y^*}{c^{R*}} + A\rho_a}{(1 - \rho_a) \frac{\mu_g k^{R*}}{c^{R*}} + \hat{a}_2 + \alpha A} \\ \hat{b}_2 &= \left( \frac{1 - \lambda\alpha}{1 - \lambda} \right) \frac{y^*}{c^{R*}} - \frac{\mu_g k^{R*}}{c^{R*}} \hat{b}_1 \\ \hat{d}_1 &= \frac{A\alpha\rho_g - (1 - \rho_g) \frac{\mu_g k^{R*}}{c^{R*}}}{(1 - \rho_g) \frac{\mu_g k^{R*}}{c^{R*}} + \hat{a}_2 + A\alpha} \\ \hat{d}_2 &= -\frac{\mu_g k^{R*}}{c^{R*}} (1 + \hat{d}_1) \end{aligned} \quad (\text{S2.14})$$

Given the total consumption of the economy as in equation (12), and making use of the equation (11) and the fact that  $W_t = \alpha Y_t$  implying  $\tilde{c}_t^L = \tilde{y}_t$ , one can arrive at the volatility of consumption relative to output as,

$$\frac{\sigma_{\tilde{c}}^2}{\sigma_{\tilde{y}}^2} = \left( \frac{c^{R*}}{c^*} \right)^2 (1 - \lambda)^2 \frac{\sigma_{\tilde{c}^R}^2}{\sigma_{\tilde{y}}^2} + \left( \frac{c^{L*}}{c^*} \right)^2 \lambda^2. \quad (\text{S2.15})$$

Here the fluctuations in a Ricardian household's consumption and that in total output are respectively,

$$\begin{aligned} \sigma_{\tilde{c}^R}^2 &= \left[ \frac{a_2^2 b_1^2}{1 - a_1^2} + b_2^2 \right] \sigma_a^2 + \left[ \frac{a_2^2 d_1^2}{1 - a_1^2} + d_2^2 \right] \sigma_{\tilde{g}}^2, \\ \sigma_{\tilde{y}}^2 &= \left[ 1 + \frac{(1 - \alpha)^2 b_1^2}{1 - a_1^2} \right] \sigma_a^2 + \left[ \alpha^2 + \frac{(1 - \alpha)^2 d_1^2}{1 - a_1^2} \right] \sigma_{\tilde{g}}^2, \end{aligned} \quad (\text{S2.16})$$

where the value of the coefficients of  $\sigma_a^2$  and  $\sigma_{\tilde{g}}^2$  in equations S2.16 can be expressed in terms of the parameters derived in S2.14.

The proof of Proposition (1) is demonstrated through a numerical analysis. The volatility of consumption and output are computed using the expressions in (S2.10), (S2.11), (S2.13) and (S2.14) evaluated with values of deep parameters, the steady state growth rate and the persistence parameters of technology and growth shock structures used in the simulation exercise in section IV. The values of the parameters in the numerical exercise are  $\beta = 0.98$ ,  $\alpha = 0.7$ ,  $\delta = 0.05$ ,  $\mu_g = 1.047$ ,  $\rho_a = 0.495$ , and  $\rho_g = 0.261$ .

## S2.II Proof of Proposition 1. (i)

Log-linearisation of  $c_t^L = W_t = \alpha y_t$  yields  $\tilde{c}_t^L = \tilde{y}_t$ . Hence  $\sigma_{\tilde{c}_t^L}^2 = \sigma_{\tilde{y}_t}^2$  proves Proposition 1. (i).

## S2.III Proof of Proposition 1. (ii)

Under the assumption of the absence of growth shock,  $\sigma_{\epsilon^g}^2 = 0$ ,  $\sigma_{\epsilon^a}^2 > 0$ , from expressions in (21), the relative consumption volatility of a Ricardian household with respect to output volatility is obtained as

$$\frac{\sigma_{\tilde{c}^R}^2}{\sigma_{\tilde{y}}^2} = \frac{\left[ \frac{a_2^2 b_1^2}{1-a_1^2} + b_2^2 \right]}{\left[ 1 + \frac{(1-\alpha)^2 b_1^2}{1-a_1^2} \right]}.$$

This ratio is evaluated at two values of  $\lambda$ . In one scenario,  $\lambda = 0.9$  that is the share of liquidity-constrained households is very high. In the second scenario, the economy is populated only by the Ricardian households, i.e.,  $\lambda = 0$ . Given the value of relative volatility of consumption of a Ricardian household with respect to output volatility, the volatility of total consumption with respect to output volatility  $\frac{\sigma_{\tilde{c}}^2}{\sigma_{\tilde{y}}^2}$  can be computed from equation (20) under two alternative state of financial development. The relative consumption volatilities are shown in Table S2.1.

**Table S2.1** Relative consumption volatility under transitory income shock

$\lambda$	$\frac{\sigma_{\tilde{c}^R}}{\sigma_{\tilde{y}}}$	$\frac{\sigma_{\tilde{c}}}{\sigma_{\tilde{y}}}$
0.900	0.745	0.807
0	0.406	0.406

The results indicate that as long as the economy contains a share of population of Ricardian type who can smooth consumption, the consumption volatility relative to output volatility is less than one under a transitory income shock. Also note that when  $\lambda = 0$ , that is the economy is populated by only Ricardian households, relative volatility of total consumption with respect to output is same as the relative consumption volatility of the Ricardian household.

## S2.IV Proof of Proposition 1. (iii)

Under the assumption of the absence of transitory income shock,  $\sigma_{\epsilon_a}^2 = 0$ ,  $\sigma_{\epsilon_g}^2 > 0$ , from expressions in (21), the relative consumption volatility of a Ricardian household with respect to output volatility is obtained as

$$\frac{\sigma_{c_R}^2}{\sigma_y^2} = \frac{\left[ \frac{a_2^2 d_1^2}{1-a_1^2} + d_2^2 \right]}{\left[ \alpha^2 + \frac{(1-\alpha)^2 d_1^2}{1-a_1^2} \right]}.$$

This ratio is evaluated for a range of values of  $\lambda$ . The highest value of  $\lambda = 0.9$  corresponds to the scenario when the share of liquidity-constrained households is very high. The lowest value that  $\lambda$  takes is 0. This scenario represents an economy with a matured financial system so that it is populated only by the Ricardian households. The values of  $\lambda$  used in the simulation exercise in section IV are also considered to evaluate relative consumption volatility of Ricardian households and that of the entire economy. Given the value of relative volatility of consumption of a Ricardian household with respect to output volatility, the volatility of total consumption with respect to output

volatility  $\frac{\sigma_{\tilde{c}}^2}{\sigma_{\tilde{y}}^2}$  can be computed from equation (20) under alternative states of financial development. The relative consumption volatilities are shown in Table S2.2.

**Table S2.2** Relative consumption volatility under permanent income shock

$\lambda$	$\frac{\sigma_{\tilde{c}^R}}{\sigma_{\tilde{y}}}$	$\frac{\sigma_{\tilde{c}}}{\sigma_{\tilde{y}}}$
0.900	1.493	0.834
0.786	1.992	1.018
0.500	3.086	1.897
0.331	3.556	2.585
0	4.223	4.223

The results indicate that the relative consumption volatility with respect to output volatility of a Ricardian household always exceeds 1. The relative volatility of total consumption with respect to output volatility depends on the level of financial development. The relative consumption volatility may fall below 1 if the economy consists of a large fraction of liquidity-constrained households.

## S2.V Proof of Proposition 1. (iv)

From Table S2.2, it is evident that the volatility of consumption of a Ricardian household and that of the total consumption with respect to output volatility increases as share of liquidity constrained households in the economy declines.

### S3 Appendix S3

Normalising all variables by the permanent component of productivity at period  $t-1$ , the following detrended system of the open economy is obtained.

The first order conditions for the Ricardian households are as follows,

$$\begin{aligned} \frac{1}{c_t^R} &= \Lambda_t \\ \Lambda_t g_t \left[ 1 + \phi \left( \frac{k_{t+1}^R g_t}{k_t^R} - \mu_g \right) \right] &= \beta \Lambda_{t+1} \left[ R_{t+1}^K + (1 - \delta) - \frac{\phi}{2} \left( \frac{k_{t+2}^R g_{t+1}}{k_{t+1}^R} - \mu_g \right)^2 \right. \\ &\quad \left. + \phi \left( \frac{k_{t+2}^R g_{t+1}}{k_{t+1}^R} - \mu_g \right) \left( \frac{k_{t+2}^R g_{t+1}}{k_{t+1}^R} \right) \right] \end{aligned} \quad (\text{S3.1})$$

where  $R_{t+1}^K = (1 - \alpha)(1 - \lambda)^{1-\alpha} e^{a_{t+1}} k_{t+1}^{R-\alpha} g_{t+1}^\alpha$ , and,

$$\Lambda_t \left[ \frac{g_t}{1 + R_t} \right] = \beta E_t \Lambda_{t+1}. \quad (\text{S3.2})$$

The budget constraint of a Ricardian household and a liquidity-constrained household are respectively as follows,

$$c_t^R + i_t^R + b_t^R - g_t \frac{b_{t+1}^R}{1 + R_t} = R_t^K k_t^R + \omega_t \quad (\text{S3.3})$$

$$(\text{S3.4})$$

and,

$$c_t^L = \omega_t \quad (\text{S3.5})$$

where

$$i_t^R = g_t k_{t+1}^R - (1 - \delta) k_t^R + \frac{\phi}{2} \left( g_t \frac{k_{t+1}^R}{k_t^R} - \mu_g \right)^2 k_t^R \quad (\text{S3.6})$$

The normalised return to labour is expressed as

$$\omega_t = \alpha e^{a_t} (1 - \lambda)^{1-\alpha} k_t^{R^{1-\alpha}} g_t^\alpha. \quad (\text{S3.7})$$

The aggregate consumption, investment, capital stock and debt are respectively,

$$c_t = \lambda c_t^L + (1 - \lambda) c_t^R, \quad i_t = (1 - \lambda) i_t^R, \quad k_t = (1 - \lambda) k_t^R, \quad b_t = (1 - \lambda) b_t^R \quad (\text{S3.8})$$

The output produced in the economy and the interest rate on bond are respectively the following

$$y_t = e^{a_t} [(1 - \lambda) k_t^R]^{1-\alpha} g_t^\alpha \quad (\text{S3.9})$$

$$R_t = R^* + \psi(e^{b_{t+1} - \bar{b}} - 1) \quad (\text{S3.10})$$

respectively. The economy-wide resource constraint is

$$c_t + i_t + t b_t = y_t \quad (\text{S3.11})$$

where

$$t b_t = b_t - g_t \frac{b_{t+1}}{1 + R_t} \quad (\text{S3.12})$$

With the initial capital stock  $k_0$ , the competitive equilibrium is defined as a set of prices and quantities  $(R_t^K, \omega_t, R_t, y_t, c_t^R, c_t^L, i_t^R, k_t^R, b_t^R, c_t, i_t, k_t, b_t, t b_t)$ , given the sequence of shocks to the transitory component of TFP and the growth rate of the permanent component of TFP, that solves the maximisa-

tion problem of the households, optimisation by the firms and satisfies the resource constraint of the economy.