Job Market Seminar

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Financial Intermediation and the Lucas Puzzle
Financial Intermediation and the Lucas Puzzle

Amir Goren*

Abstract

I consider search and matching frictions between borrowers and lenders as an explanation for the existence of financial intermediaries. I find that financial development and intermediation cause both increased welfare and stronger volatility in response to productivity shocks. In a simple open economy version of the model I solve the Lucas puzzle, explaining why capital doesn’t flow from rich to poor countries. Taking the model to the data, I find that financial development in the U.S. declined after the end of World War II until the early 1950’s, but has been improving since. India’s financial development significantly lagged that of the U.S. until the late 2000’s.

Keywords: Bank, Credit, Search, Match, Friction, Volatility, Development

JEL: E13, E2, E32, E44, E51, F21, F36, F4, F63, G14, G15

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1 Introduction

Why do banks exist? I consider search and matching frictions between borrowers and lenders as an explanation for the existence of financial intermediaries. I use a simple general equilibrium model with search frictions to analyze the consequences of the transition from bilateral to intermediated lending.

A successful bilateral match between a borrower and a lender is not certain and occurs only in probability. As a result, savers receive only probability-adjusted returns and producers obtain only probability-adjusted capital to produce with. On the other hand, an intermediary that pools lenders and borrowers creates a more centralized lending market, which alleviates the search frictions and increases the probability of finding a borrowing and lending match. Intermediation in my model increases matching probability between borrowers and lenders in three conceptual steps. First, the intermediary has a one-to-many matching technology that allows the intermediary to be matched with multiple borrowers and lenders. Second, by pooling both borrowers and lenders, the intermediary becomes a market maker. Third, the intermediary employs matching mechanisms, becoming a Walrasian auctioneer, thus increasing the matching probabilities between borrowers and lenders to 1. This three step process is not unique to financial intermediation and could be applied to other middlemen. However, I show the unique implications of bilateral vs. intermediated matching when it comes to borrowing and lending. Matching frictions in borrowing and lending affect welfare chiefly via productive capital.

The literature provides several economic justifications for financial intermediation. The first explanation views intermediaries as coalitions that provide consum-
tion risk sharing and smoothing at the cost of bank runs and accompanying economic downturns (Diamond and Dybvig, 1983). Different people may wish to consume at different times especially if they are exposed to different income shocks. The intermediary allows a consumer who has more income than she wishes to consume to deposit her excess resources while allowing a consumer who wishes to consume more than his income to borrow.

The second explanation sees intermediaries arise from information asymmetries (Leland and Pyle, 1977) and views their economic role as delegated monitors of borrowers’ private information (Williamson, 1986). Entrepreneurs who wish to borrow resources for their economic projects have private information about the risks and potential returns of their projects. In addition, after borrowing resources they may have an incentive to default on their obligations by exaggerating their losses. The intermediary’s role, according to this view, is to monitor the true state of borrowers while incurring the costs of monitoring.

A third approach views banks as institutions whose liabilities may compete with money as a means of payment (Cavalcanti and Wallace, 1999, He et al., 2005). Once money is deposited into checking accounts, which are liabilities of banks, debit cards and checks may be used as means of payment that reassign bank liabilities from buyers to sellers debiting the former and crediting the latter.

The most recent New Monetary approach shows how intermediation arises endogenously as a result of borrowers’ limited commitment (Gu et al., 2013). As in the first approach, different consumers may wish to consume at different times and would benefit from borrowing and lending except that borrowers sometimes default. Con-
sequently, it is hard for lenders to trust random borrowers. However, intermediaries that specialize in borrowing have an incentive to honor their commitment due to their repeated interactions with lenders. This superior trustworthiness of intermediaries allows borrowing and lending between consumers similar to the first explanation with the addition of the use of intermediary liabilities as means of payment as in the third explanation.

In contrast to the above theories, this paper offers a theory of evolution from bilateral to intermediated lending, where the intermediary alleviates search frictions and increases the probability of matching borrowers and lenders. This paper is most closely related to Greenwood and Jovaníć 1990 and Fuerst 1995, which belong to the information asymmetries strand of the literature. Greenwood and Jovaníć view financial intermediaries as lending coalitions, which improve the efficiency of investment by directing it to higher growth projects, thereby generating higher growth and also inequality. In my model, growth is separate and distinct from financial efficiency. Growth in my model is generated by labor-augmenting technology, as in all RBC and New-Keynesian models, whereas financial efficiency in my model affects the fraction of savings in the economy that can be used in production. Fuerst adds agency costs to a real business cycle model in order to increase its weak propagation of shocks. He finds, however, that financial frictions in the form of agency costs do not significantly amplify shocks. My model shows that reduced financial frictions in the form of higher matching probabilities amplify productivity shocks.

Less closely related literature includes Cooper and Corbae 1997 and den Haan, Ramey and Watson 1999 who focus on the breakdown of financial intermediation, and
King and Levine 1993 who focus on the connection between development of financial infrastructure to the development of physical infrastructure and innovation. My paper is also close to Besci et al. 2000 who focus on liquidity effects on participation and composition of firms’ quality. The difference between the aforementioned papers and mine is that I focus on the explanation, consequences and estimation of the level of financial intermediation.

This paper is remotely related to the Middlemen literature (Townsend 1978, Rubinstein and Wolinsky 1987) as well as to Diamond’s 1990 credit search model, which focuses on bilateral consumption credit and Kiyotaki and Wright’s (1989) description of the evolution from barter to the use of money as a medium of exchange. My work differs from the above papers in that I focus on intermediation between borrowers and lenders.

The rest of the paper is organized as follows: the second section presents a simple general equilibrium model with a bilateral borrowing and lending search friction, the third section analyzes the model. In the fourth section, I solve the Lucas puzzle using an open economy extension, and in the fifth section I address Financial Development and growth. In the sixth section, I take the model to the data of the U.S. and India, and in the seventh section I conclude.
2 Model

2.1 Bilateral Lending and Borrowing

2.1.1 Households

A homogenous continuum of households of measure 1 provide labor and lend capital to firms through a matching process that I expand on below. Households maximize an expected lifetime utility subject to a budget constraint:

$$\max E_t \sum_{j=0}^{\infty} \beta^j u(c_{t+j})$$

where $c_t$ is consumption, $\beta$ a discount factor and where the period utility is:

$$u(c_t) = \ln c_t$$

and the household’s budget constraint is:

$$a_{t+1} = (1 + r_t)a_t + w_t - c_t$$

where $a_t$ is assets or accumulated savings, $r_t$ return on lending, $w_t$ the wage and $p$ is a matching probability between households and firms that I expand on below. I assume away depreciation.

Households have a consumption smoothing pact according to which $p$ households that match with a firm pay a portion of their capital income to $1 - p$ unmatched
households, which keeps the budget constraint homogenous. Households make a take-it or leave-it offer to the firms and hence receive all the surplus from a match.

2.1.2 Firms

A continuum of firms of measure 1 that are born and destroyed in each period are used only if they obtain capital through a match with a household. The firm’s production function is:

\[ Y_t = K_t^\alpha L_t^{1-\alpha} \]

where \( Y_t \) is output, \( K_t \) capital and \( L_t \) the number of workers, which equals the number of households. The aggregate production and profit functions on a per household basis are:

\[ y_t = f(k_t) = k_t^\alpha \]

\[ \pi_t = y_t - w_t - r_t k_t \]

where \( y_t \) is output per household and \( k_t \) is capital per household. The labor market is perfectly competitive. A firm that is not matched with a household remains idle. A firm that is matched with a household deploys capital that is equal to the household’s savings \( a_t \). However, since only \( p \) firms are matched, the aggregate capital on a per
household basis is only a fraction $p$ of the household’s assets:

$$k_t = pa_t$$

A TFP shock process $z_t$ enters the production function and evolves as follows:

$$y_t = \exp(z_t)p_t^\alpha a_t^\alpha$$

$$z_t = \rho z_{t-1} + \varepsilon_t$$

where $\rho$ is the persistence and $\varepsilon_t$ a white noise shock.

In order to model a financial shock, I let matching probability $p_t$ be time-varying subject to an auto-regressive process:

$$\log(p_t) = (1 - \rho_f) \log(\bar{p}) + \rho_f \log(p_{t-1}) + \varepsilon_t^f$$

where $\bar{p}$ is its steady-state, $\rho_f$, its persistence and $\varepsilon_t^f$ is a white-noise shock.

2.1.3 Matching Technology

As mentioned above, there is a bilateral matching technology that matches households (lenders) with firms (borrowers). I use a Cobb-Douglas matching function:

$$M_t = \theta F_t^\varphi L_t^{1-\varphi}$$
where $M_t$ is the measure of matches in period $t$, $F_t$ is the measure of firms, $L_t$ the measure of households, $\varphi \leq 1$ is the weight of firms in the matching function, and $\theta \leq 1$ is the matching efficiency. Since $F_t = 1$ and $L_t = 1$, $M_t = \theta$ in each period $t$. The matching probability for the households is consequently:

$$p^H_t = \frac{M_t}{L_t} = \theta$$

and for the firms:

$$p^F_t = \frac{M_t}{F_t} = \theta$$

Thus, the matching probabilities for households and firms are equal:

$$p = \theta$$

2.2 Equilibrium

The labor market is competitive and therefore the equilibrium wage equals the marginal product of labor:

$$w_t = (1 - \alpha)y_t \quad (1)$$

Consequently, firm surplus over wages equals:

$$y_t - w_t = \alpha y_t$$
Matched households make a take-it or leave-it offer for the full surplus and therefore the interest income equals:

\[ r_t k_t = \alpha k_t^\alpha \]

where \( r_t \) is the interest rate that is received by the households. Hence, the interest rate equals:

\[ r_t = \alpha k_t^{\alpha - 1} = \alpha p^{\alpha - 1}a_t^{\alpha - 1} \tag{2} \]

The first order condition of the household with respect to savings and its budget constraint:

\[ \frac{c_{t+1}}{c_t} = \beta (1 + pr_{t+1}) \tag{3} \]

\[ a_{t+1} = (1 + pr_t)a_t + w_t - c_t \tag{4} \]

Equations 1-4 characterize the model.

### 2.3 Steady-State

The economy described above has a non-stochastic steady-state, in which the equilibrium conditions simplify to:

\[ w = (1 - \alpha)p^\alpha a^\alpha \tag{5} \]
\[ r = \alpha p^{\alpha - 1} a^{\alpha - 1} \]  
\[ 1 = \beta (1 + pr) \]  
\[ c = w + apr \]

2.4 Intermediated Lending and Borrowing

I now consider an alternate version of the model in which borrowers and lenders meet through a financial intermediary. Financial intermediation increases the matching probability between firms and households in three conceptual steps:

1. An intermediated one-to-many matching technology allows the intermediary to be matched with multiple borrowers and lenders.

2. By pooling both borrowers and lenders, the intermediary becomes a market maker.

3. The intermediary employs a matching mechanism, becoming a Walrasian auctioneer, thus reducing the matching frictions and increasing the matching probabilities between borrowers and lenders to 1.

The optimality conditions of the bilateral model (equations 1-9) hold for the intermediated case with probability of intermediated matches \( p = 1 \). Note that this version of the model is essentially the same as the standard RBC model (King et al. 1988) with fixed labor.
3 Analysis

3.1 Calibration

I calibrate the parameters of the model as follows:

<table>
<thead>
<tr>
<th>α</th>
<th>β</th>
<th>ϕ</th>
<th>θ_B</th>
<th>θ_I</th>
<th>ρ</th>
<th>ρ_f</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.38</td>
<td>0.98</td>
<td>0.5</td>
<td>0.2</td>
<td>1</td>
<td>0.975</td>
<td>0.9</td>
</tr>
</tbody>
</table>

where \( \alpha \) is the capital share of income, \( \beta \) is a quarterly discount factor, \( \varphi \) is the matching function’s weight on firms, \( \theta_B \) is bilateral matching efficiency, \( \theta_I \) intermediated matching efficiency, \( \rho \) is the persistence of a log TFP shock and \( \rho_f \) is the persistence of log financial matching shock. I assume that the financial shock is slightly less persistent than a TFP shock. The steady-state matching probabilities are determined by the matching efficiencies: \( \bar{p}_B = \theta_B, \bar{p}_I = \theta_I \).

3.2 Welfare Consequences

Using the steady state conditions I compute steady-state lifetime utility from consumption as a function of matching probabilities. The lifetime utility from consumption in steady state is:

\[
W = \ln \frac{c}{1 - \beta}
\] (9)
Figure 1 presents the steady-state welfare $W$ as a function of the matching probability $p$. As expected, steady-state welfare is strictly increasing in the matching probability.

3.3 Dynamics

I use Dynare software on top of Matlab in order to linearize the model around its non-stochastic steady-state, convert it to a reduced form and simulate its response to productivity and financial shocks.

3.3.1 Productivity Shock

Figure 2 shows the response of bilateral and intermediated versions of the model to a positive 1% productivity shock.

The intermediated economy responds to a productivity shock much like the standard RBC model with fixed labor. The TFP shock occurs in period $t = 0$, output
Figure 2: Impulse Responses to TFP Shock

[Graphs showing impulse responses for TFP Shock, Output, Consumption, Wage, Interest Rate, and Assets over time.]
in the intermediated model increases by about 4% in period \( t = 1 \) and has a hump shaped response while the output of the bilateral model increases by only about 1.5%. Consumption in the intermediated model increases by 1.5% in the first period and continues to increase to about 3.5% while in the bilateral model it increases by only 1%. The wage increases by 2.5% in the intermediated model but only increases by less than 1% in the bilateral model. The interest rate response is very weak (0.05% and 0.25%) in both models. Assets in the intermediated model increase by almost 30% but only increase by 10% in the bilateral model.

In summary, the intermediated model produces much stronger volatility than the bilateral model in response to a TFP shock. I believe that this is due to a stronger lending and borrowing channel in the intermediated model. Fuerst’s (1995) finding that financial frictions do not significantly amplify shocks are confirmed and explained by my model, which shows that it is reduced financial frictions in the form of higher matching probabilities that amplify productivity shocks.

### 3.3.2 Financial Shock

Figure 3 presents the responses of the intermediated and bilateral models to a negative 1% financial shock.

It is important to note that due to the different base line matching probabilities in the intermediated and bilateral economies the effect of a 1% shock is nominally larger in the intermediated economy than in the bilateral one. The output in the intermediated model decreases by 1.6% and only by 0.6% in the bilateral model. Consumption in the intermediated model decreases by 0.3% in the first period and
Figure 3: Impulse Response to a Financial Shock
has a hump shape. In the bilateral model consumption decreases by only 0.2%. The wage in the intermediated model decreases by 0.9% while in the bilateral model it decreases by only 0.3%. Interest rate increases slightly in both models by 0.04% in the intermediated model and 0.16% in the bilateral model. Assets respond with a hump shape and decrease by 7% in the intermediated model and only by 2% in the bilateral model. Since the steady-state matching probability in the bilateral economy is fifth of that in the intermediated economy, the nominal change in matching probability is 5 times bigger in the intermediated economy, which helps explain the different responses.

I conclude that a financially developed economy is more volatile than a less developed one. This is due to the fact that a less financially developed economy is more consumption centric and therefore, lending and borrowing play a smaller role in it. Hence, higher volatility is inherent to more efficient financial markets.

## 4 Lucas Puzzle

Poor countries have lower capital per capita than rich countries. Consequently, they should have higher marginal productivity than rich countries if their production technology is similar. Lucas (1990) asks “Why Doesn’t Capital Flow from Rich to Poor Countries?”. In this section I propose an explanation based on the model that I presented in section 2 with the key feature of matching probabilities between borrowers and lenders.

I consider a small open home country economy, with low matching probability $p$
and a foreign large open economy with high matching probability $p^*$, such that:

$$p^* > p$$

The two economies use the same production technology. If savings are allowed to flow freely from country to country, I expect the probability adjusted interest rate, which is received by savers in both countries to equalize:

$$p^* r^* = pr$$

Since $p/p^* < 1$, the interest rate in the home country remains higher than the interest rate in the foreign country $r > r^*$ and the resulting interest rate ratio is:

$$r/r^* = p^*/p$$

(10)

Further, based on equation 6, the capital per capita in both countries must obey:

$$p^* r^* = \alpha p^* k^{\alpha - 1} = \alpha p k^{\alpha - 1} = pr$$

The resulting capital per capita ratio is:

$$k^*/k = \left(\frac{p^*}{p}\right)^{\frac{1}{1-\alpha}}$$

(11)

Since $\left(\frac{p^*}{p}\right)^{\frac{1}{1-\alpha}} > 1$, the capital per capita in the home country remains lower than in the foreign country $k < k^*$ due to the lower matching probability between borrowers
and lenders in the home country.

In order to check if any capital flows from one economy to the other, I compare the capital per capita ratio of the closed economies to the capital per capita ratio of the open economies. The closed economy steady-state capital from equations 6 and 7 is:

$$k = \left( \frac{\alpha \beta p}{1 - \beta} \right)^{\frac{1}{1 - \alpha}}$$

(12)

I already assumed that both countries use the same production technology ($\alpha$). If I also assume that the discount factor $\beta$ is shared by the two economies then the capital per capita ratio of the closed economies is identical to the capital ratio in the open economies in equation 11. Hence, there is no flow of capital from one country to the other upon the opening of the economies to capital flows. Similarly, the steady-state interest rate of a closed economy from equation 7 is:

$$r = \frac{1 - \beta}{\beta p}$$

(13)

Hence, if the discount factor is shared by the two economies the interest rate ratio of the closed economies is identical to interest rate ratio of the open economies in equation 10.

The model provides the matching probability between borrowers and lenders as an explanation for why the capital per capita in different closed economies is different to begin with and why there is no flow of capital from the rich to the poor economy once the economies open to capital flows.
5 Financial Development

“One of the most important problems in the field of finance, if not the single most important one. . . is the effect that financial structure and development have on economic growth” (Goldsmith 1969). King and Levine (1993) find that there is a strong positive relationship between financial development indicators and long-run real per capita growth rates, capital accumulation and productivity growth. Levine and Zervos (1998) find that the initial level of stock market liquidity and the initial level of banking development are positively and significantly correlated with future rates of economic growth, capital accumulation, and productivity growth over the next 18 years even after controlling for initial income, schooling, inflation, government spending, the black market exchange rate premium, and political stability. Smith (2002) further notes that “Our understanding of finance and growth will be substantively advanced by the further modeling of the dynamic interactions between the evolution of the financial system and economic growth”.

In this section, I use the matching probability between borrowers and lenders $\bar{p}$ in my model as an indicator for financial development and investigate the relationship between financial development dynamics and economic growth. Financial development, expressed as a gross growth rate $\tau$ of the matching probability $\bar{p}$ between savings and investment is predicted by the model to lead to output growth. The steady-state output per capita from the production function and equation 12 is:

$$y = \left( \frac{\alpha \bar{p}}{1 - \beta} \right)^{\frac{\sigma}{\sigma - 1}}$$
Hence, a gross growth rate $\tau$ in financial development $\bar{\rho}$ leads to a gross growth rate in output:

$$\tau \frac{\alpha}{1-\alpha}$$

With a capital share of income $\alpha = 1/2$, the gross growth rate of the matching probability equals the gross growth rate in output. If the capital share is higher, it amplifies the growth in matching probability and if it is lower it dampens the growth in matching probability.

6 Estimation

6.1 Identification

In this section I estimate the steady-state as well as temporal evolution of matching probabilities $p_t$ in two economies, U.S. and India. In order to distinguish TFP or technological growth from financial development, I add technological growth to the model. Hence, the production function per household is:

$$y_t = p_t^\alpha a_t^\alpha x_t^{1-\alpha}$$

where $x_t$ is labor augmenting technology. The gross growth rate of labor-augmenting technology is $g_t = x_t / x_{t-1}$, which is subject to an auto-regressive process:
\[ g_t = (1 - \rho_\gamma)\gamma + \rho_\gamma g_{t-1} + \varepsilon_t^\gamma \]

where \( \rho_\gamma \) is the persistence, \( \gamma \) is the steady-state of gross growth rate and \( \varepsilon_t^\gamma \) is white-noise shock. Adding growth to the model changes equations 3 and 4 to:

\[ g_{t+1} + c_{t+1} = \beta (1 + p_{t+1}r_{t+1}) \] \( (14) \)

\[ g_{t+1}s_{t+1} = (1 + p_tr_t)a_t + w_t - c_t \] \( (15) \)

The steady-state equations 7 and 8 change to:

\[ \gamma = \beta (1 + \bar{p}r) \] \( (16) \)

\[ c = w + a(1 + \bar{p}r - \gamma) \] \( (17) \)

### 6.2 Estimation Method

In order to distinguish technology growth from financial development I use a non-linear model with non-zero steady states following Pfeifer 2018. I use Dynare software on top of Matlab in order to linearize the model around its steady-state, convert it to a reduced form and perform Bayesian estimation with 5 blocks of Metropolis-Hastings simulations of 200,000 iterations. I use two observable variables: output per
worker $y$, and consumption per worker $c$, both in logs and first differences. I use two structural shocks, a white noise technology growth shock $\varepsilon_\gamma^t$ with standard deviation of $\sigma_\gamma$ and a financial matching white noise shock $\varepsilon_\gamma^f$ with standard deviation of $\sigma_f$. Table 1 summarizes the prior information that I use in these estimations:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Probability Density</th>
<th>1st Moment</th>
<th>2nd Moment</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\alpha$</td>
<td>Beta</td>
<td>0.33</td>
<td>0.05</td>
</tr>
<tr>
<td>$\beta$</td>
<td>Beta</td>
<td>0.99</td>
<td>0.002</td>
</tr>
<tr>
<td>$\gamma$</td>
<td>Normal</td>
<td>1.005</td>
<td>0.001</td>
</tr>
<tr>
<td>$\bar{p}$</td>
<td>Beta</td>
<td>0.6</td>
<td>0.1</td>
</tr>
<tr>
<td>$\rho_p$</td>
<td>Beta</td>
<td>0.8</td>
<td>0.1</td>
</tr>
<tr>
<td>$\rho_g$</td>
<td>Beta</td>
<td>0.4</td>
<td>0.1</td>
</tr>
<tr>
<td>$\sigma_f$</td>
<td>Inverse-Gamma</td>
<td>0.01</td>
<td>Infinity</td>
</tr>
<tr>
<td>$\sigma_\gamma$</td>
<td>Inverse-Gamma</td>
<td>0.01</td>
<td>Infinity</td>
</tr>
</tbody>
</table>

6.3 Data

For the U.S. I use Real GDP divided by the Civilian Labor Force and for consumption per capita I use the sum of Real Personal Consumption and Real Government Consumption divided by the Civilian Labor Force from 1948 to 2019. For India I use Real GDP and the sum of Private Final Consumption and Real Government Consumption divided by Number of Persons Engaged from 1996 to 2018.

6.4 Results

I report the Bayesian estimates of the parameters for both countries in the Appendix. In order to compare the smoothed variables of interest for both countries I use the
same persistence parameter $\rho_f$ and $\rho_\gamma$, based on the estimated parameter of the U.S., for both countries.

Figure 4: Smoothed Technology Growth and Financial Development

![Technology Growth and Financial Development](image)

Figure 4 depicts smoothed gross technology growth rates and the matching probabilities for the U.S. and India. Technology growth rate in India has been more
volatile than that of the U.S. throughout the sample data.

Financial Development in the U.S. declined after the end of World War II from a matching probability of 0.65 to under 0.45 by the early 1950’s and has been improving since to a matching probability of above 0.65. India’s Financial Development lagged that of the U.S. until the late 2000’s when it surpassed that of the U.S.

7 Conclusions

I have modeled a general equilibrium economy with matching probabilities in borrowing and lending. Using the model I computed the welfare as a function of matching probability and found that steady-state welfare is strictly increasing in matching probability. However, the dynamic analysis shows that there is a volatility price that more financially developed economies pay for higher welfare. As saving and borrowing become more important in the economy they also amplify both productivity and financial shocks. Hence, both increased welfare and higher volatility are inherent to financial development and intermediation.

I have shown that the open economy extension of the model solves the Lucas puzzle by explaining why capital doesn’t flow from rich to poor countries due to the lower matching probability between borrowers and lenders in the latter.

Taking the model to the data I estimated both the model parameters and the smoothed trajectories of technology growth along with matching probabilities between borrowers and lenders for the U.S. and India. Financial Development in the U.S. declined after the end of World War II from a matching probability of 0.65 to
under 0.45 by the early 1950’s and has been improving since to a matching probability of above 0.65. India’s Financial Development lagged that of the U.S. until the late 2000’s when it surpassed that of the U.S.

Appendix

Figures 5 and 6 present the prior and posterior probability densities for the estimated parameters of the model for the two countries: U.S. and India.

The parameters names are described in table 2:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\varepsilon_f$</td>
<td>SE_epsp</td>
</tr>
<tr>
<td>$\varepsilon_g$</td>
<td>SE_epsg</td>
</tr>
<tr>
<td>$\alpha$</td>
<td>calpha</td>
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<tr>
<td>$\beta$</td>
<td>cbeta</td>
</tr>
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<td>$\gamma$</td>
<td>gamma</td>
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<td>$\bar{p}$</td>
<td>pbar</td>
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<tr>
<td>$\rho_{f}$</td>
<td>rohp</td>
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<tr>
<td>$\rho_{\gamma}$</td>
<td>rohg</td>
</tr>
</tbody>
</table>

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Figure 5: Bayesian Estimation of Parameters for the U.S.
Figure 6: Bayesian Estimation of Parameters for India

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