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An Estimated Labor and Financial Friction Model: Evidence from the Korean Economy*

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Abstract This study uses a DSGE model with a financial accelerator mechanism and involuntary unemployment to analyze the Korean economy. First, the fully specified model outperforms the New Keynesian model in terms of implied volatilities. Second, the structural shocks in the financial friction model have more amplification effects on macroeconomic variables than those in the New Keynesian model. Third, the "Fisher deflationary effect" is not significant. Fourth, the contributions of domestic shocks are more pronounced than those of foreign shocks. Fifth, the financial risk shock has a significant effect on investment. Sixth, the global financial crisis was driven by aggregate demand shocks, aggregate supply shocks, and foreign shocks. However, the pandemic crisis was mostly driven by adverse aggregate supply shocks, while the adverse foreign shocks' contributions were short-lived. Seventh, policy shocks played important roles in dampening the adverse effects of shocks, especially on output and unemployment rates.

Keywords DSGE model, financial accelerator, involuntary unemployment

JEL Classification C11; E24; E30; E44; F41; G10

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1. INTRODUCTION

Rare episodes, such as the global financial crisis, have often challenged the conventional framework of economic models and simultaneously provided an opportunity for modifications. Along with the series of economic booms and busts, several macroeconomic models, such as dynamic stochastic general equilibrium (DSGE) models have been developed by synthesizing various types of friction and structural shocks. One of the many recent notable propositions of DSGE models is, for example, a financial friction model that incorporates the balance sheet effects of a financial constraint. Financial friction models have been receiving wide attention ever since the global financial crisis of 2007–2008 severely damaged the real activities of the global economy and required an unprecedented magnitude of macroeconomic policy interventions.

More recently, the coronavirus disease 2019 (COVID-19) pandemic has emerged as a new episode, challenging the existing frameworks of economic analysis. One of the many questions in macroeconomics regarding this pandemic is whether this event should be interpreted as an aggregate supply or demand shock. Identifying the type of shock is an important agenda because only then can a relevant policy response be proposed to mitigate the economic predicament due to the quarantine measures implemented by many countries.

The Korean economy was no exception to the two episodes of the global financial crisis and COVID-19 pandemic. Consequently, the Korean economy can be a good test bed to examine how DSGE models can explain these historical records. This study attempts to empirically assess the Korean economy through the lens of the most up-to-date DSGE model. To reflect the recent developments of DSGE modeling, the DSGE model employed in this study adopts financial friction, while retaining New Keynesian features such as price and wage rigidities. This study particularly focuses on the role of financial friction in explaining the business cycle properties of the Korean economy and also the historical records via comparison with a standard New Keynesian model without financial friction.

There are two popular approaches for the financial friction in DSGE models. The first approach is to allow collateral in the borrowing constraint, as in Kiyotaki and Moore (1997). The introduction of this collateral constraint amplifies the mechanism of an aggregate shock through the balance sheet effect, depending on the level of net asset. This specification has been successfully applied to identify the relationship between business cycle fluctuations and real estate prices, as in Iacoviello (2005) and Iacoviello and Neri (2010). However, this approach is too sensitive to various structural parameters, such as the ratio of financially constrained households, a degree of heterogeneity between idiosyncratic productivities and the elasticity of inter-temporal substitution in utility, as Mendicino (2012), Kocherlakota (2000), and Cordoba and Ripoll (2004) have mentioned.

The second approach is to introduce a financial accelerator mechanism, as in Bernanke *et al*. (1999). The model identifies the financial leverage cost induced by a risk-hedging debt contract between a financial intermediary and a risk-neutral entrepreneur. In other words, financial risk is reflected in the borrowing price, in contrast to the collateral constraint. This model similarly produces an amplification mechanism for an aggregate shock, albeit via the countercyclical financial leverage cost. Moreover, the financial accelerator model has an advantage, especially in terms of empirical analysis, since the price measures of the financial market, such as loan interest rate and deposit interest rate, are identified, which can be directly mapped into data, in contrast to quantity measures. Exploiting this advantage, Christensen and Dib (2008) and Christiano *et al*. (2010) have applied this model to large-scale DSGE models for various empirical analyses.

In addition to financial friction, the labor friction of involuntary unemployment á la Galí (2011) is added to the model in this study. The class of standard New Keynesian DSGE models does not normally specify labor market variables by distinguishing between employment and unemployment, but it often assumes an abstract form. Consequently, the model without labor friction will be limited to explaining either labor hours or employment only. However, the labor friction adopted in this study simultaneously identifies employment and unemployment and, hence, naturally implies labor force participation as well. The advantages of this specification are twofold. First, both labor market indicators (i.e., unemployment and employment rates) can be used for the estimation. This addition potentially enhances the identification of structural parameters, especially those related to the labor market. Second, this addition provides a full picture of the labor market from both sides: labor supply and labor demand. As Erceg and Levin (2014) have argued, the evidence that business cycle factors account for the labor force participation around the global financial crisis in 2007–2008 and its persistent decline afterward suggests that a single measure, such as the unemployment rate by itself, cannot solely represent the labor market. With labor friction, the model will be able to distinguish between labor supply (mainly explained by labor force participation) and labor demand (mainly by the employment rate), while the excess labor supply is identified by the unemployment rate.

Several studies have applied extended DSGE models, departing from stan-

Table 1: Related literature on the Korean economy

	Economy	Financial Friction	Labor Friction	Banking
Gertler et al. (2007)	SOE	similar to BGG	X	X
Chung* (2011)	SOE	BGG	X	X
Lee* (2011)	Closed	KM & BGG	X	X
Alp et al. (2012)	SOE	BGG	X	X
Moon and Lee* (2012)	SOE	GGN	X	X
Kim* (2012)	SOE	BGG	X	X
Bae* (2013)	SOE	BGG	X	O
Kang and Suh (2017)	SOE	BGG	Matching	X
Joo* (2019)	Closed	BGG	X	O
Kim and Lee (2016)	SOE	X	Involuntary	X

* : References in Korean

SOE : Small Open Economy, Closed : Closed Economy

BGG : Bernanke *et al*. (1999), KM : Kiyotaki and Moore (1997), GGN : Gertler *et al*. (2007)

dard New Keynesian models, to analyze the Korean economy. Table (1) summarizes those studies that particularly use financial frictions, except for Kim and Lee (2016), who apply involuntary unemployment. The earliest financial friction model that was applied to the Korean economy was that of Gertler *et al.* (2007), who demonstrated that the financial accelerator model[1] duly captured the financial crisis of 1997–1998 and the counterfactual experiment implied that the fixed exchange rate would have exacerbated the crisis. 정용승 (2011) similarly adopted the financial accelerator model and showed that the monetary policy designed in response to the exchange rate was not desirable in terms of social welfare, while the model also accounted for the behavior of the Korean economy during the global financial crisis of 2007–2008. Alp *et al.* (2012) also confirmed that the counterfactual experiments under the financial accelerator model implied that the exchange rate flexibility and interest rate cuts implemented by the Bank of Korea substantially softened the impact of the global financial crisis in 2007–2008. 문외솔, 이윤수 (2012) illustrate the responses of macroeconomic variables with various structural shocks using the estimated model and find that the business cycle fluctuations of exchange rate, external debt, and investment are substantially affected by the country risk premium shock via the financial accelerator mechanism. 김건홍 (2012) and 배병호 (2013) also report that the es-

[1]The financial accelerator model refers to Bernanke *et al*. (1999), while the collateral constraint model refers to Kiyotaki and Moore (1997).

timated models show a significant influence of financial market disturbances on investment and output in terms of business cycle fluctuations. In addition, 배병호 (2013) finds that the monetary policy established in response to the exchange rate or asset prices improves social welfare compared to the conventional Taylor rule that responds to the output gap and inflation gap only. Interestingly, this is a contrasting result from 정용승 (2011) in the case of the exchange rate responding to the monetary policy. The significant difference between 정용승 (2011) and 배병호 (2013) seems to be the introduction of the banking sector[2] that identifies the spread between the lending and deposit interest rates. Although the author has not explicitly analyzed the role of the banking sector by comparing one with it and one without it, these results seem to imply that the monetary policy responding to the exchange rate is likely to stabilize the economy via the banking sector channel.

주동헌 (2019) adopts the financial accelerator mechanism in both the firm and banking sectors and confirms that the estimated model implies that the financial accelerator mechanism is more important for the firm's business cycle behaviors relative to the banking sector. However, the model assumes a closed economy that is restricted to domestic macroeconomic conditions only. 이준희 (2011) also assumes a closed economy model but adopts both a financial accelerator mechanism and collateral constraint. While the collateral constraint dampens the effect of total factor productivity (TFP) shock, the financial accelerator mechanism amplifies the effect of monetary policy shock. Finally, Kang and Suh (2017) adopt the financial accelerator model and labor market friction with a search and matching framework, which is a key departure from previous studies. They found that a household's weak bargaining power suppressed the real wage increase during the recovery period after the global financial crisis of 2007—2008, while the unemployment rate decreased. However, this model lacks the ability to identify the labor market participation rate, which is potentially important for explaining labor market behaviors during and after the global financial crisis, as Erceg and Levin (2014) have mentioned.

The model employed in this study adopts the financial accelerator mechanism, involuntary unemployment, small open economy, and banking sector. The model specifications adopted in this study are complementary to the previous literature that analyzes the Korean economy. First, as the Korean economy is heavily influenced by foreign conditions, the assumption of a small open economy seems natural. Second, this study focuses on the role of financial friction in terms of business cycle fluctuations by comparing the benchmark model with the

[2]The model follows Edwards and Végh (1997).

standard New Keynesian model without financial friction. The comparison will be mainly analyzed with simulation exercises, such as impulse response functions, variance decompositions, and implied volatilities of variables. Third, the involuntary unemployment specification allows us to not only utilize the employment and unemployment rates simultaneously[3] but also assess the types of structural shocks that have contributed toward these labor market variables during two crisis periods, namely, the global financial crisis and COVID-19 pandemic, by demonstrating historical decompositions. Although the banking sector specification in this study is not a crucial departure, it is assumed to extend the data dimension because it includes observation series, such as the lending and deposit interest rates, which can potentially help in the estimation of structural parameters related to the financial market. Finally, the sample period of the data for estimation covers the recent COVID-19 pandemic period and thus provides new empirical evidence through the lens of this proposed model.

In the following, Section (2) illustrates the benchmark model; Section (3) shows the estimation results, various simulations, and historical decompositions; while Section (4) summarizes and concludes this paper.

2. MODEL

The key departure of Bernanke *et al*. (1999) financial accelerator model from the standard New Keynesian model is the identification of an entrepreneur and a financial intermediary. The entrepreneur is a risk-neutral agent who operates the capital stock to provide capital services to goods-producing firms. The entrepreneur has access to the financial market to borrow from financial intermediaries, such as banks, so that debt financing is possible. In addition to this financial accelerator mechanism, involuntary unemployment á la Galí (2011) is identified in this model. The model explanation presented below is illustrated in detail only with those key departures, while the rest of the model, which consists of New Keynesian components with a small open economy assumption, is summarized in the appendix in terms of equilibrium conditions[4].

[3]Note that the information set of these two labor market indicators will be same as using the labor market participation rate and unemployment rate.

[4]The New Keynesian model with the small open economy assumption for the Korean economy is close to that of Kim (2014), except for the non-stationary growth of output. The model employed herein focuses only on business cycle fluctuations; thus, all the variables are stationary.

2.1. CAPITAL PRODUCER

The capital market is perfectly competitive; therefore, a representative capital producer can be assumed. The capital producer purchases the physical capital stock after depreciation, $(1-\delta)k_{t-1}^{s}$, from the entrepreneur in the current period, and sells the next period's physical capital stock, k_t^s, by producing capital stock with a new investment, i_t[5]. The following equation is the physical capital evolution process with an investment adjustment cost[6].

$$k_t^s = (1-\delta)k_{t-1}^s + \xi_t^i\left(1 - S\left(\frac{i_t}{i_{t-1}}\right)\right)i_t \tag{1}$$

The price of the capital stock, q_t, varies over time due to the investment adjustment cost. In addition, an investment-specific technology shock, ξ_t^i, is added to explain the business cycle fluctuation of the investment. By denoting the relative price of the capital stock, q_t, and that of the investment, $\frac{p_t^i}{p_t}$, the profit function of this capital producer is

$$\Pi_t^k \equiv q_t k_t^s - q_t(1-\delta)k_{t-1}^s - \frac{p_t^i}{p_t}i_t$$

The profit maximization of this problem under the capital evolution process, (1) above, provides the optimality conditions[7] associated the capital stock, k_t^s, and the investment, i_t.

2.2. ENTREPRENEUR

There exists a continuum of risk-neutral entrepreneurs, indexed by j. At period t, the j^{th} entrepreneur purchases the capital stock, $k_{j,t}$, which will be utilized in the next period, with their own real net worth, $nw_{j,t}$, in addition to debt, $d_{j,t}^e$, financed by financial intermediaries. Hence, the following constraint is the balance sheet of the j^{th} entrepreneur.

$$d_{j,t}^e = q_t k_{j,t} - nw_{j,t} \geq 0 \tag{2}$$

Each entrepreneur faces an idiosyncratic productivity shock, which is a source of heterogeneity among entrepreneurs. This entrepreneur-specific shock is reflected

[5]We distinguish the physical capital stock, k_t^s, from capital service, k_{t+1}^d, as capital service reflects the capital utilization, u_{t+1}. Thus, $u_{t+1}k_t^s = k_{t+1}^d$.

[6]A quadratic investment adjustment cost function, $S\left(\frac{i_t}{i_{t-1}}\right)$, is assumed, as in (F.2).

[7]See optimality conditions (A.1) and (A.2) in the Appendix.

in the capital services that are provided to the goods-producing firms. We denote this idiosyncratic shock by ω, which is assumed to have a log-normal probability density.

$$\Pr[\omega \leq x] = F\left(x; \sigma_t^{\omega}\right)$$

The above-mentioned probability density for $\log \omega$ has a mean of μ^{ω} with a standard deviation of σ_t^{ω}[8]. Moreover, σ_t^{ω} is an exogenous volatility process that is referred to as "financial risk shock," as in Christiano *et al.* (2014). Furthermore, the information on the j^{th} idiosyncratic productivity, ω_j, is hidden so that information asymmetry is present. Owing to this asymmetry, a costly state verification problem arises, as will be discussed further herein.

To derive the optimal debt contract between the entrepreneur and the financial intermediary at period t, the expected return at period $t+1$ should be explicitly illustrated. Therefore, let us first start with the decision on capital utilization, u_{t+1}, at period $t+1$ after the idiosyncratic productivity shock, $\omega_{j,t+1}$, is realized. The j^{th} entrepreneur decides on the capital utilization, u_{t+1}, to maximize the following profit[9]:

$$\max_{u_{t+1}} \left[u_{t+1} r_{t+1}^k \left(1-\tau_k\right) - \frac{\Phi\left(u_{t+1}\right)}{\xi_{t+1}^i} + \frac{\delta \tau_k}{\xi_{t+1}^i} \right] \omega_{j,t+1} k_{j,t}^s$$

The entrepreneur provides the capital service[10], $u_{t+1}\omega_{j,t+1}k_{j,t}^s$, to the firms from which the entrepreneur earns $r_{t+1}^k\left(1-\tau_k\right)$ after tax for each unit of capital service. The entrepreneur also bears a capital utilization cost[11], $\frac{\Phi(u_{t+1})}{\xi_{t+1}^i}$, and receives a tax deduction from the depreciation of capital stock, $\frac{\delta\tau_k}{\xi_{t+1}^i}$. After utilizing the capital, the entrepreneur resells the remaining physical capital stock to the capital producer at the end of period $t+1$. Thus, the gross return from operating one unit of physical capital stock for the entrepreneur, R_{t+1}^k, can be summarized as in (A.4).

Based on the expected return at period $t+1$, the entrepreneur needs financial leverage to purchase the new physical capital from the capital producer at the

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[8] μ^{ω} satisfies $\int_0^{\infty} \omega dF\left(\omega; \sigma^{\omega}\right) = 1$

[9] Note that u_{t+1} is not j specific because of the symmetric optimality conditions between entrepreneurs, which will be evident, as in (A.3)

[10] Note that $k_{j,t+1}^d = u_{t+1}k_{j,t}^s$. Thus, the market-clearing condition for the physical capital market is $\int_0^{\infty} \omega k_{j,t}^s dF(\omega) = k_t^s$, whereas that for the capital service market is $\int_0^{\infty} \omega u_{t+1} k_{j,t}^s dF(\omega) = k_{t+1}^d$.

[11] See (F.1).

end of period t. Financial leverage is attained via a standard debt contract with a financial intermediary. The standard debt contract, as in Townsend (1979), is a result of the costly state verification problem of idiosyncratic productivity in the future. The contract states that the financial intermediary provides the funds, for instance, $d^e_{j,t}$, and, in return, the entrepreneur pays a gross interest rate[12], $Z_{j,t+1}$, if the idiosyncratic productivity is above a certain threshold level, say, $\bar{\omega}_{j,t+1}$. Furthermore, the contract also specifies that if the idiosyncratic productivity is below the threshold level, the financial intermediary bears the auditing cost to verify the true state of the entrepreneur and acquires the remaining book value of the entrepreneur's asset. This threshold value, under which the entrepreneur decides to default, is, in other words, a cut-off value for the idiosyncratic productivity that should satisfy the following condition:

$$\bar{\omega}_{j,t+1} R^k_{t+1} q_t k^s_{j,t} = Z_{j,t+1} d^e_{j,t} \tag{3}$$

This condition implies that the interest that the entrepreneur pays back to the financial intermediary should be indifferent to the return from operating capital stock under the productivity whose level is at the cut-off value.

Given the standard debt contract between these two entities, the financial intermediary's zero-profit condition can be exploited, as the financial intermediary sector is assumed to be perfectly competitive. Given the optimality condition of the financial intermediary, the expected return from the loan to the entrepreneur should be equal to the market-wide loan rate, for instance, R^e_t. Thus, the zero-profit condition of the financial intermediary is

$$\left(1 - F\left(\bar{\omega}_{j,t+1};\sigma^{\omega}_t\right)\right) Z_{j,t+1} d^e_{j,t} + (1-\mu_e) \int_0^{\bar{\omega}_{j,t+1}} \omega dF\left(\omega;\sigma^{\omega}_t\right) R^k_{t+1} q_t k^s_{j,t} = R^e_t d^e_{j,t} \tag{4}$$

The first term on the left-hand side is the expected return when the entrepreneur's productivity is above the cut-off value, while the second term is the return when the productivity is below the cut-off value. Using (3) and introducing auxiliary variables to represent the probabilistic density functions, the zero-profit condition can be rearranged as in (A.5).

The entrepreneur chooses the capital stock purchase, $k_{j,t}$, at period t and also a schedule of cut-off value, $\bar{\omega}_{j,t+1}$, for each realization of aggregate shocks in

[12] This interest rate does not depend on the idiosyncratic productivity shock; however, it does so on the realization of the aggregate shocks. In a sense, this interest rate is idiosyncratic risk-free, but not aggregate risk-free.

period $t+1$. Hence, the optimization problem is

$$\max_{k_{j,t}} \mathbb{E}_t \left[\max_{\bar{\omega}_{j,t+1}} \left\{ \int_{\bar{\omega}_{j,t+1}}^{\infty} \left(R_{t+1}^{k} q_t \omega k_{j,t} - Z_{j,t+1} d_{j,t}^{e} \right) dF\left(\omega; \sigma_t^{\omega}\right) \right\} \right]$$

under the zero-profit condition, as in (4). Note that the choice of the cut-off value, $\bar{\omega}_{j,t+1}$, is within the expectation sign because it should be chosen for each aggregate state in period $t+1$. The optimality condition for $k_{j,t}$ will be j-specific and, thus, cannot summarize the equilibrium condition for the entrepreneurial sector. To induce the equilibrium condition in terms of aggregate variables only, the optimization problem of the entrepreneur should be stated in terms of the capital to net-worth ratio or debt to capital ratio. Only then can the optimality conditions be symmetric across the entrepreneurial sector. Therefore, by defining $\kappa_{j,t} \equiv \frac{q_t k_{j,t}}{nw_{j,t}}$ and using the balance sheet constraint, (2), the problem can be restated as follows:

$$\max_{\kappa_{j,t}} \mathbb{E}_t \left[\max_{\bar{\omega}_{j,t+1}} \left\{ \left(1 - \Gamma\left(\bar{\omega}_{j,t+1}; \sigma_t^{\omega}\right)\right) \frac{R_{t+1}^{k}}{R_t^{e}} \right\} \right] \kappa_{j,t}$$

subject to (A.5). (A.6), which is the first-order condition associated with $\bar{\omega}_{j,t+1}$, implies that $\bar{\omega}_{j,t+1} = \bar{\omega}_{t+1}$. Consequently, $\frac{d_{j,t}^{e}}{q_t k_{j,t}^{s}} = \frac{d_t^{e}}{q_t k_t^{s}}$ due to (A.5) and $\kappa_{j,t} = \kappa_t$.

To maintain the stationarity of the accumulating net-worth, the entry and exit of the entrepreneurs are assumed to be determined exogenously. With $1-\zeta_t$ probability, the entrepreneurs exit, while a fixed amount of start-up funds, W^e, is added to the book value of entrepreneurs. Thus, the aggregate net-worth of the entrepreneurial sector is

$$nw_t = \zeta_t V_t + W^e$$

V_t is the entrepreneurs' book value before exit and entry, which follows the process in (A.7). ζ_t is the survival probability, which is a function of an exogenous process, $\tilde{\zeta}_t^{e}$. A disturbance to this exogenous process is the financial wealth shock.

$$\zeta_t = \frac{1}{1 + \exp\left(-\bar{\zeta}^{e} - \tilde{\zeta}_t^{e}\right)}$$

The remaining book values for the exited entrepreneurs are either consumed away, c_t^e, or transferred back to households, T_t^e.

$$\begin{aligned} (1+\tau_c)\, c_t^{e} &= (1-\zeta_t)\, \gamma_e V_t \\ T_t^{e} &= (1-\zeta_t)(1-\gamma_e)\, V_t \end{aligned}$$

2.3. FINANCIAL INTERMEDIARY

The banking sector consists of financial intermediaries that provide financial mediation between households' deposits and entrepreneurs' loans. The banking sector is assumed to be perfectly competitive, and thus, the problem, henceforth, can be solved in representative terms. The financial intermediary receives deposits, d_t^h, from households and lends funds, d_t^e, to entrepreneurs. This financial intermediary must hold a certain level of reserves with a portion, γ_b, of the deposits, while also bearing the costs of providing services to both households and entrepreneurs. These cost functions are Γ_t^h and Γ_t^e, which are, in a sense, reduced forms that may characterize the behaviors of financial intermediaries[13]. In sum, the period t profit function for the financial intermediary is

$$\Pi_t^b = R_{t-1}^e \frac{d_{t-1}^e}{\Pi_t} + \Gamma_t^h (1-\gamma_b) d_t^h - R_{t-1}^h \frac{d_{t-1}^h}{\Pi_t} - \Gamma_t^e d_t^e.$$

R_t^h is the deposit interest rate and R_t^e is the loan interest rate. The cost functions associated with financial services are

$$\begin{aligned} \Gamma_t^h &= \exp\left(\Gamma^{h_0} - \Gamma^{h_1}\left(\frac{\tilde{d}_t^h}{\tilde{d}_t^e} - \frac{\bar{d}^h}{\bar{d}^e}\right) + \xi_t^h\right) \\ \Gamma_t^e &= \exp\left(\Gamma^{e_0} - \Gamma^{e_1}\left(\frac{\tilde{d}_t^h}{\tilde{d}_t^e} - \frac{\bar{d}^h}{\bar{d}^e}\right) + \xi_t^e\right) \end{aligned}$$

The cost functions are assumed to be elastic to the aggregate deposit–loan ratio[14], $\frac{\tilde{d}_t^h}{\tilde{d}_t^e}$. In this way, when the deposit–loan ratio exceeds the steady-state level, the net receipts from deposits reduce, and thus, the costs associated with deposit services rise, while the costs to loan services reduce. In addition, there are constant terms, Γ^{h_0} and Γ^{e_0}, in the cost functions that explain the interest rate spreads at the steady state, as will be made clearer with the equilibrium conditions presented below. Moreover, these cost functions allow for fluctuations by the exogenous disturbances, ξ_t^h and ξ_t^e, respectively.

[13]A structural form of the banking sector may be modeled as in Christiano *et al*. (2014), but we decide to identify the banking sector in a rather parsimonious way as this paper does not pay attention to the micro-founded behaviors of the banking sector.

[14]This deposit–loan ratio is assumed not to be specific to the financial intermediary, implying that the representative financial intermediary does not internalize its own deposit–loan ratio but rather depends on the aggregate level. If internalized, the cost function derivatives are $\Gamma_t^e\left(1-\Gamma^{e_1}\frac{d_t^h}{d_t^e}\right)$와 $\Gamma_t^h\left(1-\Gamma^{h_1}\frac{d_t^h}{d_t^e}\right)$. However, these functions do not qualitatively alter the overall dynamics of the model.

Thus, the representative financial intermediary chooses deposit, d_t^h, and loan, d_t^e, to maximize the following stream of profits that are discounted with the stochastic discount factor because this entity is owned by households.

$$\max_{d_t^e, d_t^h} \mathbb{E}_t \sum_{\tau=t}^{\infty} \beta^{\tau-t} \frac{\lambda_\tau}{\lambda_t} \Pi_\tau^b$$

The FOCs associated with this problem after relating to the household's equilibrium conditions are as follows:

$$\Gamma_t^e R_t = R_t^e \quad (5)$$
$$(1-\gamma_b)\Gamma_t^h R_t = R_t^h \quad (6)$$

Thus, the spread between the risk-free interest rate and loan interest rate is explained by Γ_t^e, and the spread between the risk-free interest rate and deposit interest rate is described by $(1-\gamma_b)\Gamma_t^h$. Furthermore, these spreads are elastic to the financial soundness of the financial intermediaries. Combining those two conditions, (5) and (6), the steady state implies that

$$\frac{(1-\gamma_b)\exp\left(\Gamma^{h_0}\right)}{\exp\left(\Gamma^{e_0}\right)} = \frac{R^h}{R^e}$$

Summarily, the loan–deposit interest rate spread is identified in a reduced form, which is in terms of these cost functions.

2.4. HOUSEHOLDS

There exists a continuum of homogenous households and a continuum of heterogeneous household members within a representative household. Household members are assumed to differ in two dimensions: types of labor service and labor supply disutilities. To specify these two-dimensional identifications, household members are indexed by a pair, $(i, j) \in [0,1] \times [0,1]$, which lies in a unit square. The first index, $i \in [0,1]$, is a labor service type in which a household member specializes, while the second index, $j \in [0,1]$, measures the relative degree of the disutility by providing the labor service. As in Merz (1995) and Galí (2011), the income risks among the household members are fully shared within the household and, thus, allocations, such as consumption, are symmetric regardless of their job status[15]. Hence, the lifetime utility of a representative household

[15] In addition, the utility function needs to be separable between labor supply and consumption.

is

$$
\begin{aligned}
V_0 &\equiv \mathbb{E}_0 \int_0^1 \sum_{t=0}^{\infty} \beta^t \upsilon_t \left\{ \log\left(c_{it}^h - \vartheta_c c_{it-1}^h\right) + \psi_d \frac{\left(d_{it}^h\right)^{1-\vartheta_d}}{1-\vartheta_d} - \varphi_t \psi_n \int_0^{n_{it}^s} j^{\vartheta_n} dj \right\} di \\
&= \mathbb{E}_0 \int_0^1 \sum_{t=0}^{\infty} \beta^t \upsilon_t \left\{ \log\left(c_{it}^h - \vartheta_c c_{it-1}^h\right) + \psi_d \frac{\left(d_{it}^h\right)^{1-\vartheta_d}}{1-\vartheta_d} - \varphi_t \psi_n \frac{\left(n_{it}^s\right)^{1+\vartheta_n}}{1+\vartheta_n} \right\} di
\end{aligned}
$$

Each household member, j, bears a disutility of j^{ϑ_n}, and the overall disutilities of the household are an integral of those of the household members, specified by n_{it}^s, who are employed in the i type of labor market. Note that ϑ_n is the inverse of the Frisch elasticity, while ψ_n is the substitution elasticity.

Deposit in utility[16] is assumed in this model to induce a supply of deposits to the financial intermediaries, and this can be interpreted as a reduced form that may reflect households' needs for financial services. The function form shows that this term is separable from consumption and labor supply, although it has an elasticity of ϑ_d and a substitution elasticity of ψ_d.

Finally, some of the features that are common in medium-scale New Keynesian models, such as habit consumption, whose degrees are parameterized by ϑ_c and two preference disturbances, υ_t and φ_t, are adopted. υ_t is an intertemporal preference shock, as in Primiceri *et al.* (2006), and φ_t is a labor supply shifter, as in Hall (1997) and Chari (2007).

The household member i's budget constraint is

$$
\begin{aligned}
& (1+\tau_c)\frac{p_t^c}{p_t} c_{it}^h + d_{i,t}^h + b_{it} + ex_t b_{it}^W + W^e \\
= \; & (1-\tau_w) w_{it} n_{it}^s + R_{t-1}^h \frac{d_{it-1}^h}{\Pi_t} \\
& + R_{t-1}\frac{b_{it-1}}{\Pi_t} + R_{t-1}^W \Gamma^W(\cdot) \frac{ex_t b_{it-1}^W}{\Pi_t} + T_t^g + T_t^e + \Pi_t^h
\end{aligned}
$$

p_t is the numerarie in the model. p_t^c is the price of the final consumption goods, which is a composite of domestic and imported goods. d_{it}^h is the deposit holdings and b_{it} is the government bond holdings, while R_t^h and R_t are the interest rates associated with these two holdings, respectively. Households pay start-up funds for the entrepreneurs. w_{it} is the wage rate for an i-type labor service when employed, which is n_{it}^s. τ_c and τ_w are the consumption and wage taxes, respectively. T_t^g is a lump-sum transfer from the government[17], T_t^e is some portion of

[16] This specification is similar to money in utility that generates the money demand.

[17] Negative means the lump-sum tax.

the remaining assets from exited entrepreneurs, and Π_t^h summarizes all the profits earned from the ownerships of other entities, such as capital producers, financial intermediaries, final goods producers, intermediate goods producers, and import and export goods distributors.

The open economy's feature is reflected in this model by specifying the foreign bond holdings from the international financial market. Each household member has foreign bond holdings, b_{it}^W, which are specified in terms of foreign currency, and the exchange rate, ex_t, is considered in the budget constraint. The foreign interest rate, R_t^W, is exogenous to domestic households because of the assumption of a small open economy. To fill the gap between the domestic and foreign interest rates, the country risk premium, $\Gamma^W(\cdot)$, is specified. This premium takes the functional form of (F.3). The premium has a constant parameter that can be calibrated to match the long-run average spread between the domestic and foreign interest rates. Furthermore, it has time-varying components, a debt-elastic term, and an exogenous shock. The debt-elastic term guarantees the stationarity of the small open economy model, as shown in Schmitt-Grohé and Uribe (2003).

The equilibrium conditions, except for the labor-related variables, can be derived through a standard optimization problem, as shown in (A.12)—(A.15). The labor market-related variables due to labor market friction that induces involuntary unemployment require some additional explanations. First, labor market participation can be identified by the incentive compatibility condition of household members. For instance, the i^{th} household member only participates in the labor market when the following condition is satisfied:

$$w_{it} \geq \frac{d_t \varphi_t \psi_n \left(\ell_{it}^s\right)^{\vartheta_n}}{\lambda_t \left(1-\tau_w\right)}$$

Let $\ell_t^s \equiv \int_0^1 \ell_{it}^s di$ be the labor market participation rate[18]. The above-mentioned condition states that the wage for the i type should be greater than or equal to the right-hand side, which is the disutilities of labor supply converted into monetary units[19]. The marginal participant satisfies the equality of this condition, hence,

$$\ell_{it}^s = \left(\frac{\lambda_t \left(1-\tau_w\right) w_{it}}{\upsilon_t \varphi_t \psi_n}\right)^{\frac{1}{\vartheta_n}}$$

[18]Note that this is different from the employed labor supply, n_t^s.

[19]λ_t is the Lagrangian multiplier of the household's optimization problem.

Aggregating over the labor service type i,

$$\ell_t^s = \left(\frac{\lambda_t (1-\tau_w)}{\upsilon_t \varphi_t \psi_n} \right)^{\frac{1}{\vartheta_n}} \left(w_t^L\right)^{\frac{1}{\vartheta_n}}$$

where $\left(w_t^L\right)^{\frac{1}{\vartheta_n}} \equiv \int_0^1 w_{it}^{\frac{1}{\vartheta_n}} di$. This is the labor market participation equilibrium condition because it is expressed in terms of aggregate variables only[20]. Moreover, using this definition, the unemployment rate is one minus the employment rate - labor market participation rate ratio, $\frac{n_t^d}{\ell_t^s}$.

$$u_t^e \equiv 1 - \frac{n_t^d}{\ell_t^s} \tag{7}$$

where the employment rate is $n_t^d \equiv \int_0^1 n_{it}^s di$. Hence, the unemployment rate is an excess labor supply that is caused by the monopolistic power of differentiated labor services[21]. While the employment rate represents the labor demand and labor participation is driven by the labor supply, the unemployment rate may react to any disturbance to both labor demand and supply. Hence, the response of the unemployment rate is determined through the relativity between the labor demand and supply.

3. EMPIRICAL ANALYSIS

The model specified in this paper is brought to an estimation using Bayesian methodology with data from the Korean economy. This section begins with a data description, followed by the results from the estimation. In addition, simulation exercises, such as impulse response functions, are reported, and the historical decompositions of the variables of interest are investigated at the end of this section.

3.1. DATA

Table 2 summarizes the sample data for the macroeconomic variables used for the estimation. Since the 1950s, the Korean economy has experienced many structural changes, including the 1997 financial crisis, to reconcile with a highly

[20] The transition process, $\left(w_t^L\right)^{\frac{1}{\vartheta_n}}$, can be expressed in terms of aggregate variables only, as in (A.51), once the integration is taken into account.

[21] Galí (2011) shows that the unemployment rate is positively related to the wage markup.

parameterized model, such as DSGE. Therefore, the sample data start from the year 2000, so that relatively more stable periods for the Korean economy are considered. Gross domestic products (GDP) and its expenditure components, such as consumption, investment, government spending, and exports, are from national income accounts. The risk-free interest rate is the government's treasury bond with one-year maturity, and the inflation rate is based on the consumer price index[22]. Unemployment and employment rates are used as labor market indicators[23]. The foreign interest rate is the US treasury bill with a three-month maturity. The deposit interest rate is the savings deposit interest rate, and the loan interest rate is the business loan interest rate.

Table 2: Sample data

Data	Units	SA	Periods	Source	Notations
GDP	₩(2015)	SA	2000:Q1-2021:Q4	ECOS	y_t^o
Private Consumption	₩(2015)	SA	2000:Q1-2021:Q4	ECOS	c_t^o
Private Investment	₩(2015)	SA	2000:Q1-2021:Q4	ECOS	i_t^o
Gov't Consumption	₩(2015)	SA	2000:Q1-2021:Q4	ECOS	g_t^o
Export	₩(2015)	SA	2000:Q1-2021:Q4	ECOS	x_t^o
1-yr Treasury Bond	Annual %	NSA	2000:Q1-2021:Q4	ECOS	R_t^o
CPI	2015=100	NSA	2000:Q1-2021:Q4	KOSIS	Π_t^o
Unemployment Rate	%	SA	2000:Q1-2021:Q4	KOSIS	$u_t^{e,o}$
Employment Rate	%	SA	2000:Q1-2021:Q4	KOSIS	n_t^o
3-month U.S. treasury bill	Annual %	NSA	2000:Q1-2021:Q4	FRED	$R_t^{W,o}$
Deposit Interest Rate	Annual %	NSA	2000:Q1-2021:Q4	ECOS	$R_t^{h,o}$
Loan Interest Rate	Annual %	NSA	2000:Q1-2021:Q4	ECOS	$R_t^{e,o}$

ECOS : Bank of Korea database

KOSIS : Korea Statistics Bureau database

FRED : St. Louis Federal Reserve database

This study focuses on business cycle implications; thus, detrended time series data are necessary to match stationary variables in the model. The following vectors show how the time series data are mapped to the variables in the theoretical model. The GDP and its expenditure components are detrended by the Hodrick–Prescott filter[24]. This kind of data treatment is less common with Bayesian estimations, and GDP growth rates may be a better option. However, we decide to use the Hodrick–Prescott filter because the GDP growth rates have been declining, even within the sample periods. For instance, the average growth

[22]CPI is seasonally adjusted by using Eviews package's ARIMA X-13.

[23]Note that the labor participation rate is reproduced jointly by those two rates and thus becomes redundant in the information set for the estimation.

[24]Tilde notations on variables represent H–P filtered series, while hat notations on variables represent the log-deviations from steady states

rate in the 2000s is approximately 4 to 5%, while in the 2010s, it ranges between approximately 2 to 3%. Hence, the potential output of the Korean economy is hardly identified by the GDP growth rates. However, as the Korean economy seems to have almost converged to a balanced growth path recently, future empirical analysis may be able to apply growth rates instead of filtering methods, as observations are collected over time.

Interest and inflation rates are considered to be stationary in principle and thus used in levels, while the structural parameters associated with the long-run levels of these variables are calibrated to match the means of the data, as explained in the following subsection. The labor market indicators are also used in these levels. However, the long-run steady states implied by the model are not calibrated but are instead allowed to be estimated. Hence, a comparison between the means of the data on labor market variables and the implied steady states of these variables in the estimated model is necessary to check the plausibility of the estimation.

$$\begin{array}{ccc} \text{Variables in the model} & & \text{Observed Data} \\ \begin{bmatrix} \hat{y}_t^s \\ \hat{c}_t \\ \hat{i}_t \\ \hat{g}_t \\ \hat{x}_t \\ R_t \\ \Pi_t \\ u_t^e \\ n_t^d \\ R_t^W \\ R_t^h \\ R_t^e \end{bmatrix} & = & \begin{bmatrix} \tilde{y}_t^o \\ \tilde{c}_t^o \\ \tilde{i}_t^o \\ \tilde{g}_t^o \\ \tilde{x}_t^o \\ R_t^o \\ \Pi_t^o \\ u_t^{e,o} \\ n_t^o \\ R_t^{W,o} \\ R_t^{h,o} \\ R_t^{e,o} \end{bmatrix} \end{array}$$

3.2. CALIBRATIONS

The calibration schemes are listed in Tables 3 and 4. Table 3 shows the steady states of some selected macroeconomic variables that are calibrated to match the long-run means of the sample data. The risk-free interest rate is 3.25% per annum, which is the mean of the one-year government treasury bond. Accordingly, interest rate spreads are calibrated to match the differences in the long-run means between the government treasury bond interest rate and deposit/loan interest rates. The long-run annual inflation rate is 2%, which is the current target rate of the Bank of Korea. The government debt-to-GDP and government spending-to-GDP ratios are 35% and 14.5%, respectively.

Table 3: Calibrated steady states

Variables	Values	Descriptions
R_{ss}	$\exp(0.0325)^{.25}$	Risk-free Interest Rate
Π	$1.02^{.25}$	Target/Long-run Inflation Rate
$\frac{R^h_{ss}}{R_{ss}}$	$\exp(-0.0064)$	Deposit-Risk free Interest Rates Spread
$\frac{R^e_{ss}}{R_{ss}}$	$\exp(0.0025)$	Loan-Risk free Interest Rates Spread
$\bar{\bar{b}}$	0.35	Government Debt-Aggregate Demand Ratio
$\frac{g_{ss}}{y^d_{ss}}$	0.1480	Government Spending-Aggregate Demand Ratio

Table 4 lists the parameters calibrated in the model. The subject discount factor is pinned down by the Euler equation of the household's equilibrium conditions because the inflation rate and risk-free interest rate are already calibrated. The capital income share and depreciation rate are common values in the literature. The government debt elasticity is assumed to be 0.05, while three types of tax rates are borrowed from Kim (2014), wherein the effective tax rates are computed based on the fiscal balance data of the Korean government. Home biases are assumed to reflect a greater preference for domestic goods in consumption and more concentration on foreign imported goods in investment[25]. Parameters related to financial friction, such as entrepreneurs' cut-off values for default, survival rate, and consumption ratio, are borrowed from Kang and Suh (2017). The parameters for the cost functions of financial services are calibrated to match the spreads presented in Table 3.

3.3. MODEL ESTIMATION

The Bayesian estimation methodology is adopted for the model. To implement the estimation and perform various simulation exercises using the estimated model, the model is linearized around the deterministic steady states. Because the structural parameters are highly nonlinear, the random walk Metropolis–

[25]For instance, Korean manufacturing businesses rely heavily on imported goods such as raw materials and equipment.

Table 4: Calibrated parameters

Parameters	Values	Descriptions
β	$\frac{\Pi}{R_{ss}}$	Subjective discount factor
ψ_d	0.05	Elasticity of deposit in utilities
α	0.3	Capital income share
δ	0.025	Depreciation rate
T_1	0.05	Government debt elasticity
n^c	0.85	Home bias in consumption goods
n^i	0.35	Home bias in investment goods
τ_c	0.14	Consumption tax rate
τ_w	0.35	Wage tax rate
τ_k	0.13	Capital income tax rate
$\Gamma^{R_0^W}$	0.00465	Domestic-Foreign interest rate spread
μ_e	0.1	Monitoring cost
$\bar{\omega}$	implies 5% default rate	Entrepreneurs' cut-off value for default
ζ	0.976	Entrepreneurs' survival rate
γ_e	0.10	Entrepreneurs' consumption ratio
γ_b	0.07	Banks' reserve ratio
Γ^{h_0}	$\frac{R^h_{ss}}{R_{ss}}/(1-\gamma_b)$	Deposit-bond interest rates spread
Γ^{e_0}	$\frac{R^e_{ss}}{R_{ss}}$	Loan-bond interest rates spread

Hasting algorithm is applied, and the proposal density is based on the mode computed by the Monte Carlo optimization method in Dynare package program[26]. The measurement errors were not specified because there was no stochastic singularity problem[27]. For the convergence of chains, two and half million Monte Carlo Markov Chain draws after the two and half million initial burn-in draws are collected to report the posterior distributions. Tables 5 and 6 report the prior and posterior distributions of the structural parameters. Most prior distributions follow conventions in the literature, as pioneered by Smets and Wouters (2005).

Structural parameters such as the inverse Frisch elasticity, ϑ_n, wage rigidity, θ_w and substitution elasticity between differentiated labor services, η, are

[26] The acceptance rate was 34.11%, indicating a reasonable property of the proposal density.

[27] There are 15 structural shocks in the model, while the observables are 12.

Table 5: Prior and posterior distributions I

	Description	Prior Distr.			Posterior Distr.				
		Distr.	Mean	St. Dev.	Mode	Mean	St. Dev.	5%	95%
ϑ_c	Habit persistence	Beta	0.50	0.20	0.0963	0.0717	0.0459	0.0406	0.1590
ϑ_n	Inverse of Frisch labor elasticity	Gamma	1.50	0.50	4.5653	4.8115	0.4437	3.9707	5.1326
ϑ_d	Deposit elasticity	Gamma	1.50	0.50	3.5610	3.3361	0.4798	3.0092	4.1885
ψ_n	Labor supply s.e.	Normal	9.00	2.00	7.2478	7.7863	1.5181	5.3633	9.2791
κ	Investment adjustment cost	Normal	5.00	1.00	5.2065	5.0853	0.7494	4.2512	6.1868
ϕ_2	Capital utilization cost	Beta	0.50	0.20	0.6895	0.7261	0.1382	0.5004	0.8673
Γ^{b^W}	Country risk premium	Beta	0.50	0.15	0.1559	0.1880	0.0611	0.0905	0.2374
ε	Domestic good s.e.	Normal	8.00	1.50	8.4913	7.4570	1.1959	6.9594	10.0603
ε_M	Import good s.e.	Normal	8.00	1.50	9.0350	9.0014	1.5722	7.1090	10.9705
ε_x	Export good s.e.	Normal	8.00	1.50	8.6205	9.3436	1.3398	6.8653	10.3397
ε_W	Foreign good s.e.	Normal	8.00	1.00	8.3655	7.9877	0.9047	7.2032	9.5388
ε_c	Domestic/foreign consumption s.e.	Normal	8.00	1.50	1.1433	1.1208	0.0275	1.1118	1.1768
ε_i	Domestic/foreign investment s.e.	Normal	8.00	1.50	7.3619	7.9784	1.2136	5.7810	8.9180
η	Labor service s.e.	Normal	8.00	1.50	6.4724	6.2440	0.5989	5.7592	7.2929
θ_p	Domestic price rigidity	Beta	0.50	0.15	0.2418	0.2551	0.0841	0.1350	0.3558
θ_M	Import price rigidity	Beta	0.50	0.15	0.2162	0.3523	0.0809	0.1164	0.3290
θ_x	Export price rigidity	Beta	0.50	0.15	0.4609	0.4444	0.0833	0.3526	0.5707
θ_w	Wage rigidity	Beta	0.50	0.10	0.1150	0.1028	0.0308	0.0796	0.1550
χ	Good price indexation	Beta	0.50	0.15	0.4457	0.4481	0.1689	0.2308	0.6804
χ_M	Import price indexation	Beta	0.50	0.15	0.4129	0.3887	0.1551	0.2201	0.6328
χ_x	Export price indexation	Beta	0.50	0.15	0.5557	0.7781	0.1365	0.3739	0.7364
χ_w	Wage indexation	Beta	0.50	0.15	0.3130	0.3274	0.1224	0.1616	0.4820
γ_R	Taylor rule: interest rate smoothing	Beta	0.75	0.15	0.8490	0.8376	0.0234	0.8184	0.8778
γ_π	Taylor rule: inflation gap	Normal	1.50	0.15	1.6469	1.5515	0.1240	1.4883	1.8078
γ_y	Taylor rule: output gap	Normal	0.25	0.05	0.0602	0.0350	0.0497	-0.0019	0.1253
$\gamma_{g_{ex}}$	Taylor rule: exchange rate gap	Beta	0.25	0.10	0.2444	0.1283	0.0789	0.1453	0.3495
γ_{g_y}	Fiscal rule: automatic stabilizer	Beta	0.50	0.10	0.3942	0.3893	0.0855	0.2869	0.5071
Γ^c	Consumption import cost	Beta	0.50	0.15	0.4812	0.4184	0.1312	0.3093	0.6535
Γ^i	Investment import cost	Beta	0.50	0.15	0.4242	0.5006	0.1538	0.2260	0.6347

Note: 1) Posterior distributions are based on second half of five million MCMC draws.
2) Statistics of posterior distributions are rounded up to four decimal places.
3) “s.e.” stands for substitution elasticity.

Table 6: Prior and posterior distributions II

	Description	Prior Distr.			Posterior Distr.				
		Distr.	Mean	St. Dev.	Mode	Mean	St. Dev.	5%	95%
ρ_A	TFP AR(1)	Beta	0.50	0.15	0.6552	0.6242	0.0706	0.5643	0.7471
ρ_{ξ_i}	Investment technology AR(1)	Beta	0.50	0.15	0.4842	0.5176	0.0975	0.3562	0.6087
ρ_υ	Intertemporal preference AR(1)	Beta	0.50	0.15	0.8761	0.8646	0.0291	0.8384	0.9121
ρ_φ	Intratemporal preference AR(1)	Beta	0.50	0.15	0.9026	0.8992	0.0326	0.8594	0.9426
ρ_g	Gov't consumption AR(1)	Beta	0.50	0.15	0.6085	0.5909	0.0793	0.5068	0.7093
ρ_{R_w}	Foreign interest rate AR(1)	Beta	0.50	0.15	0.9252	0.9363	0.0229	0.8948	0.9534
ρ_{b_w}	Country premium AR(1)	Beta	0.50	0.15	0.7474	0.7423	0.0663	0.6608	0.8304
ρ_{y_w}	Foreign demand AR(1)	Beta	0.50	0.10	0.4953	0.4509	0.0902	0.3804	0.6133
ρ_{π_w}	Foreign inflation AR(1)	Beta	0.50	0.10	0.4289	0.5545	0.0782	0.3285	0.5301
ρ_μ	Price markup AR(1)	Beta	0.50	0.15	0.6345	0.6104	0.1010	0.4962	0.7508
ρ_{σ_ω}	Financial risk AR(1)	Beta	0.50	0.15	0.5503	0.5327	0.0834	0.4427	0.6579
ρ_ζ	Financial wealth AR(1)	Beta	0.50	0.15	0.4952	0.5537	0.1308	0.3322	0.6706
ρ_{ξ_h}	Deposit rate premium AR(1)	Beta	0.50	0.15	0.8690	0.8695	0.0422	0.8132	0.9210
ρ_{ξ_e}	Loan rate premium AR(1)	Beta	0.50	0.15	0.7072	0.6727	0.0776	0.6037	0.8053
$\sigma_{R,y}$	Correlation R^w, y^w	Normal	0.00	0.25	0.0077	0.0225	0.0422	-0.0405	0.0560
$\sigma_{R,\pi}$	Correlation R^w, Π^w	Normal	0.00	0.25	0.0119	-0.0109	0.0365	-0.0302	0.0563
$\sigma_{\pi,y}$	Correlation Π^w, y^w	Normal	0.00	0.25	0.0263	0.0526	0.3003	-0.3889	0.4065
$\sigma_{y,\pi}$	Correlation y^w, Π^w	Normal	0.00	0.25	0.0205	0.1818	0.2675	-0.3200	0.3760
μ_{ξ_h}	Deposit rate premium MA(1)	Beta	0.50	0.15	0.3904	0.3273	0.0994	0.2664	0.5177
μ_{ξ_e}	Loan rate premium MA(1)	Beta	0.50	0.15	0.4301	0.4721	0.0942	0.3072	0.5509
σ_υ	Intertemporal preference shock s.d.	InvGamma	0.01	0.10	0.0175	0.0141	0.0024	0.0146	0.0207
σ_φ	Intratemporal preference shock s.d.	InvGamma	0.01	0.10	0.0258	0.0293	0.0027	0.0223	0.0294
σ_{ξ_i}	Investment technology shock s.d.	InvGamma	0.01	0.10	0.0786	0.0746	0.0155	0.0594	0.0988
σ_A	TFP shock s.d.	InvGamma	0.01	0.10	0.0078	0.0077	0.0006	0.0070	0.0086
σ_m	Monetary policy shock s.d.	InvGamma	0.01	0.10	0.0016	0.0016	0.0002	0.0014	0.0019
σ_g	Government consumption shock s.d.	InvGamma	0.01	0.10	0.0080	0.0076	0.0006	0.0072	0.0088
σ_{R_w}	Foreign interest rate shock s.d.	InvGamma	0.01	0.10	0.0013	0.0013	0.0001	0.0012	0.0015
σ_{b_w}	Country risk premium shock s.d.	InvGamma	0.01	0.10	0.0055	0.0057	0.0015	0.0039	0.0074
σ_{y_w}	Foreign demand shock s.d.	InvGamma	0.01	0.10	0.0077	0.0088	0.0052	0.0034	0.0143
σ_{π_w}	Foreign inflation rate shock s.d.	InvGamma	0.01	0.10	0.0064	0.0066	0.0020	0.0041	0.0090
σ_{σ_ω}	Financial risk shock s.d.	InvGamma	0.01	0.10	0.1252	0.1289	0.0164	0.1049	0.1466
σ_ζ	Financial wealth shock s.d.	InvGamma	0.01	0.10	0.0635	0.0043	0.1144	0.0040	0.2777
σ_{μ_d}	Price markup shock s.d.	InvGamma	0.01	0.10	0.0077	0.0070	0.0015	0.0060	0.0096
σ_{ξ_h}	Deposit rate premium shock s.d.	InvGamma	0.01	0.10	0.0015	0.0015	0.0001	0.0013	0.0017
σ_{ξ_e}	Loan rate premium shock s.d.	InvGamma	0.01	0.10	0.0013	0.0013	0.0001	0.0011	0.0014

Note: 1) Posterior distributions are based on second half of five million MCMC draws.
2) Statistics of posterior distributions are rounded up to four decimal places.
3) "s.d." stands for standard deviation.

Table 7: Labor market indicators: Estimated model vs. Data

	Estimated Model*	Data
Unemployment Rate	3.66%	3.60%
Employment Rate	59.86%	59.90%
Participation Rate	62.14%	62.14%

* Estimated model is based on steady states implied by posterior modes.

key parameters that determine employment and unemployment rates. However, instead of investigating each parameter's posterior distribution separately, the implied steady states of the labor market indicators are worth examining, as previously mentioned. Table 7 shows the implied steady states of three labor market variables and the long-run means of the sample data.

The estimated model approximately matches the first moments of the labor market indicators' data. Moreover, the implied steady state of the participation rate exactly matches the mean of the data because of the definition of unemployment specified as (7) in the model, even though it is not used as an observable.

The Calvo–Yun probability parameters that reflect price and wage rigidities are worth mentioning herein. These are estimated to be particularly low compared to typical evidence from the US economy, as in Christiano *et al.* (2005) and Smets and Wouters (2005). This result presumably implies that the short-run non-neutrality of money is weaker than that of the US economy. However, the model has a financial accelerator mechanism that may have induced the low estimates of rigidities, unlike the standard New Keynesian models. Therefore, an additional estimation was performed with a New Keynesian model without the financial accelerator mechanism[28]. The estimation results are presented in Tables 10 and 11 in the Appendix. Interestingly, the estimates for the rigidity parameters in the New Keynesian model are all higher than those in the financial friction model. Hence, it is difficult to conclude whether the money non-neutrality is weak or not before making assessments based on a comparison of impulse response functions.

3.4. MODEL SIMULATIONS

This subsection reports the impulse responses to five structural shocks: investment technology shock, TFP shock, monetary policy shock, foreign interest

[28]The New Keynesian model estimated in this paper still has the labor market friction, while the entrepreneurial sector and the banking sector are deleted.

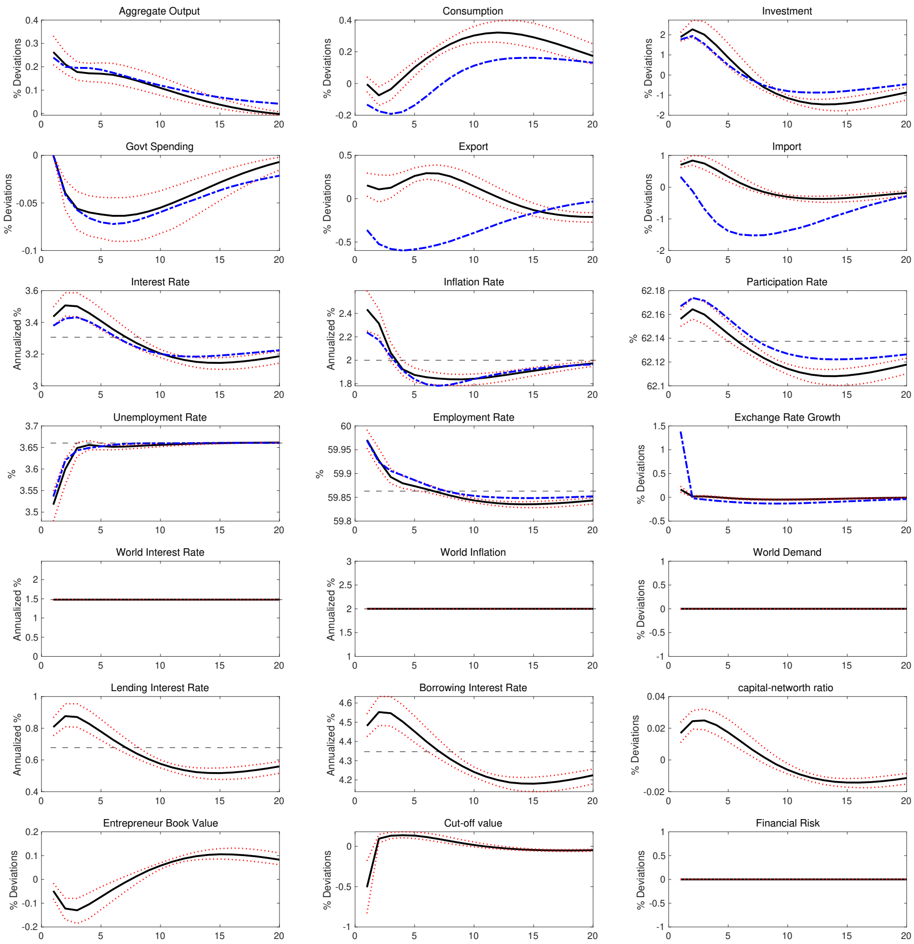
rate shock, and financial risk shock[29]. First, a positive investment technology shock directly induces an investment increase owing to its efficiency in investment goods, as shown in figure 1. Consequently, employment and output rise, whereas unemployment declines. In addition, real wages rise and consumption increases with a delay. As the overall aggregate demand increases, the inflation rate increases, thereby inducing an increase in the interest rate that follows the Taylor rule. Moreover, the investment increase is comparatively stronger for more than a year compared with the New Keynesian model. This is possible through the external financing of the entrepreneurs in the financial friction model, which is evident from the increase in the capital–net-worth ratio that is absent in the New Keynesian model. Stark differences are also apparent in exports and imports. In particular, imports rise strongly in the financial friction model but not so much in the New Keynesian model, and even decline starting from the second period. Similarly, exports increase in the financial friction model as opposed to a decrease in the New Keynesian model. Hence, the financial accelerator mechanism amplifies investment responses, imports, and exports by increasing the leverage in response to investment technology shocks.

Figure 2 shows the impulse response function of the TFP shock. A positive TFP shock increases the output while it decreases the inflation rate because it is an aggregate supply shifter. As aggregate income is equivalent to output due to national income identity, the income increase induces a positive wealth effect, and thus reduces labor participation. However, the employment rate further decreases, resulting in an increased unemployment rate. This phenomenon is a well-known result of the features of the New Keynesian model in which labor demand and real wage decline in response to a positive TFP shock[30]. The difference between the financial friction model and the New Keynesian model lies in the output, investment, export, and import responses. Output and investment increase more in the financial friction model, while exports and imports both increase, in contrast to the New Keynesian model. Two forces are at play in these impulse response functions. First, the deflationary effect induces the price competitiveness of exports in the international market and, at the same time, stronger domestic demands for domestic goods relative to imported goods. Second, the deflationary effect also affects the financial condition of entrepreneurs in the financial friction model. Given that debt contracts are established based on nominal prices, deflation exacerbates the real debt burden of entrepreneurs

[29] The rest of the IRFs are presented in the Appendix

[30] On the other hand, the pure RBC model has labor demand increasing in response to TFP shock.

Figure 1: IRFs to investment technology shock, $\varepsilon_t^{\xi_i}$



1. Black solid lines are posterior median IRFs.
   Red dotted lines are Bayesian credible intervals with lower bound, 10%, and upper bound, 90%.
   Black dashed lines are the steady state levels of selected variables; interest rates, inflation rates, and labor market indicators.
   Blue dash-dotted lines are IRFs of the New Keynesian model.
2. Units on y-axis may differ across variables: % is percentage in levels, % deviation is log-deviation from steady states and Annualized % is percentage per annum.

with the price rigidity present. This is known as "Fisher deflation channel," as explained by Christiano *et al*. (2010). Hence, leverage decreases, as reflected by the decline in the capital–net-worth ratio. However, the overall results indicate that investment rises strongly, implying that the "Fisher deflation channel" is not so pronounced with this estimated model. Furthermore, output rises mainly due to meeting the increase in foreign demand for domestic goods. This result seems to be due to the relatively weak price rigidities of the estimated financial friction model. Therefore, the financial friction model amplifies the responses of output, investment, exports, and imports with regard to the TFP shock.

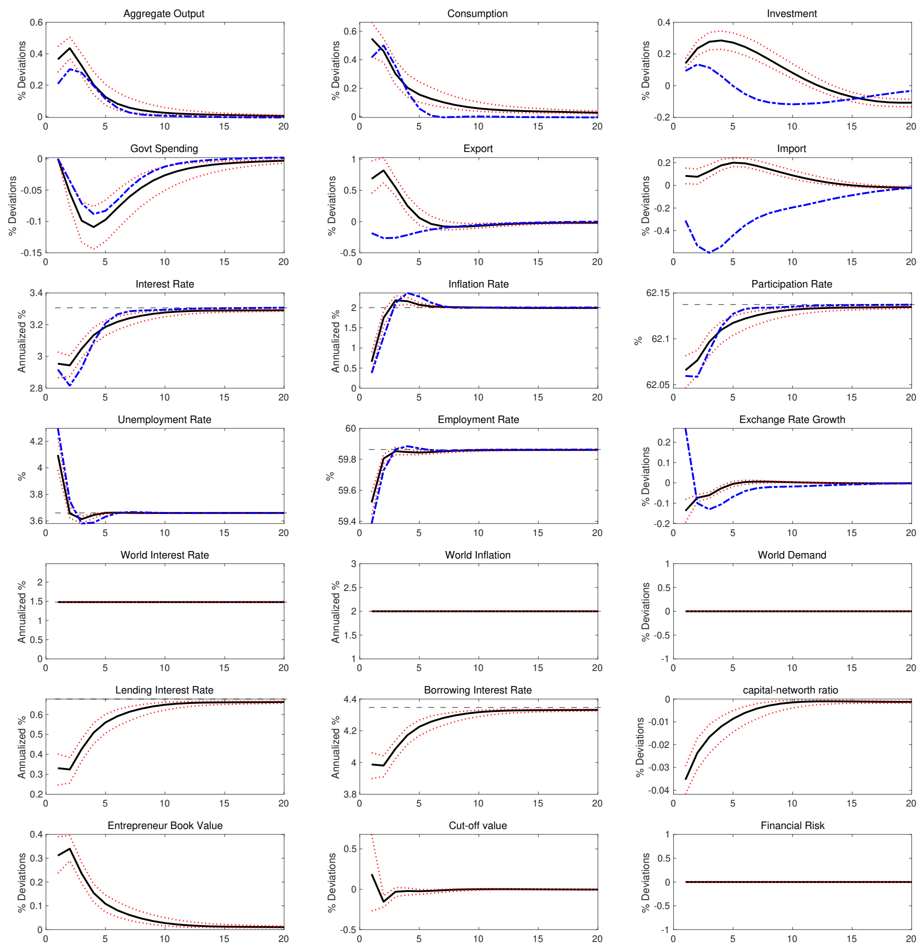
Figure 3 shows the impulse response functions of the monetary policy shock. The impulse response functions are drawn based on one standard deviation of the monetary shock; therefore, the quantitative magnitudes rely on the posterior estimates of the shock's volatility. The interest rate rises approximately by 25bp in the financial friction model and approximately by 35bp in the New Keynesian model. Nevertheless, the contractionary effect on output in the financial friction model is stronger than that in the New Keynesian model. This result is somewhat surprising, considering that price and wage rigidities are estimated to be lower in the financial friction model. The contractionary monetary policy raises the external financing cost that entrepreneurs must bear, thus reducing investment further and in a more persistent way.

Figure 4 shows the impulse response functions of the foreign interest rate shock. The balance of payments in the model in which foreign reserves are absent implies an exact trade-off between the financial and current account balances. Foreign interest rate increases induce capital outflows to satisfy the uncovered interest rate parity condition. Nonetheless, net exports should be increased to offset capital outflow. This is mainly driven by more exports in the financial friction model, but by even less imports in the New Keynesian model. Hence, the output rises in the financial friction model, which is in contrast with the New Keynesian model. Output expansion gives rise to labor demand, while labor supply also increases, but less. Consequently, the unemployment rate declines in the financial model.

Finally, the impulse response functions for the financial risk shock that is only present in the financial friction model are plotted in Figure 5. A financial risk shock substantially increases the cut-off value, and the aggregate book value declines more than the capital. Thus, the capital–net-worth ratio increases. This shock generates an overall contraction for most macroeconomic variables, except for consumption and export.

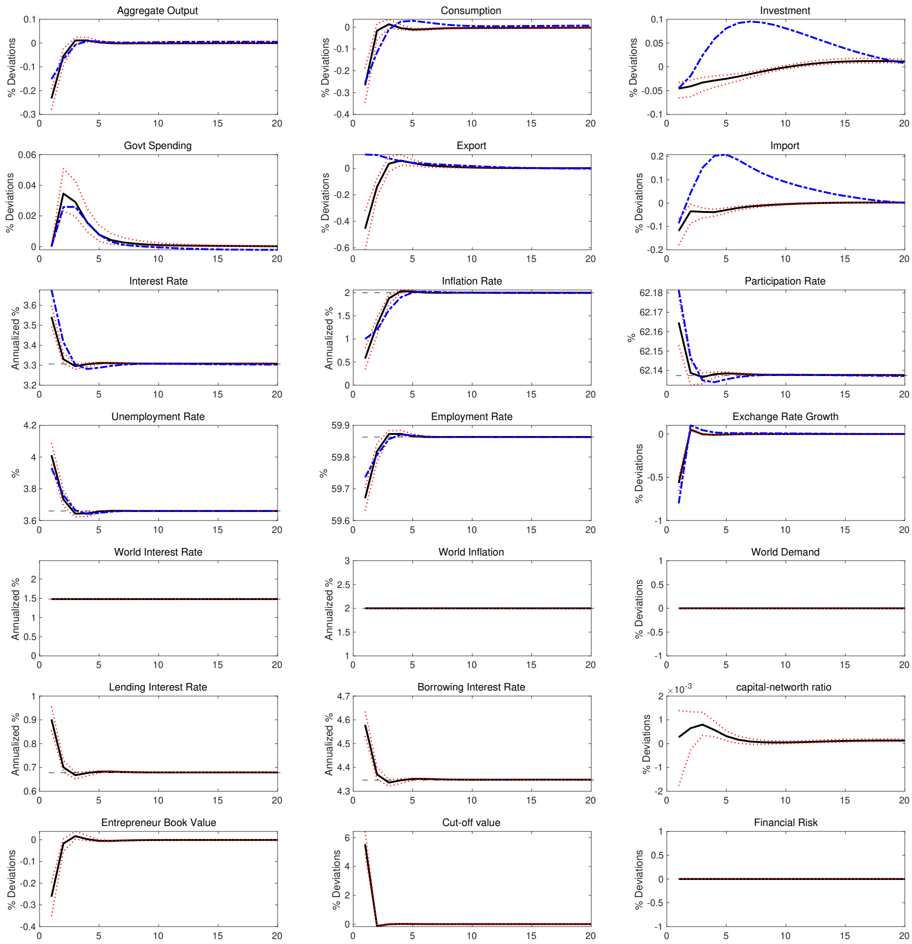
Table 8 shows the long-run variance decompositions for both the financial

Figure 2: IRFs to TFP shock, ε_t^A



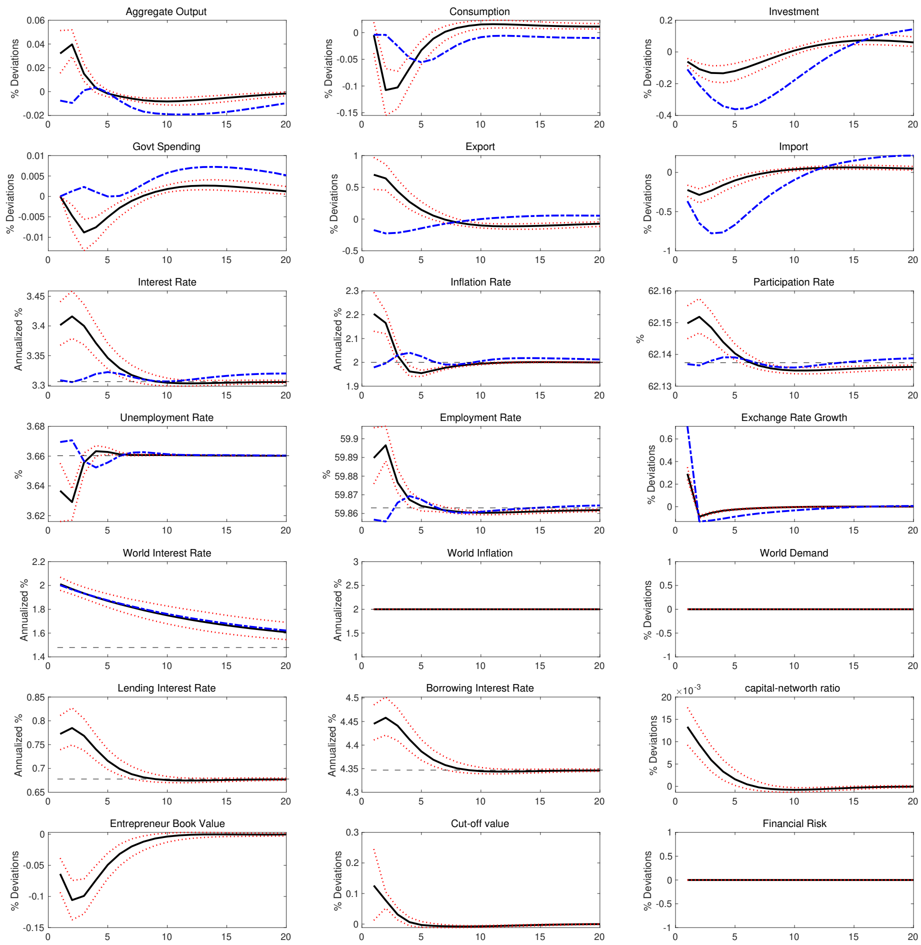
1. Black solid lines are posterior median IRFs.
   Red dotted lines are Bayesian credible intervals with lower bound, 10%, and upper bound, 90%.
   Black dashed lines are the steady state levels of selected variables; interest rates, inflation rates, and labor market indicators.
   Blue dash-dotted lines are IRFs of the New Keynesian model.
2. Units on y-axis may differ across variables: % is percentage in levels, % deviation is log-deviation from steady states and Annualized % is percentage per annum.

Figure 3: IRFs to monetary policy shock, ε_t^m



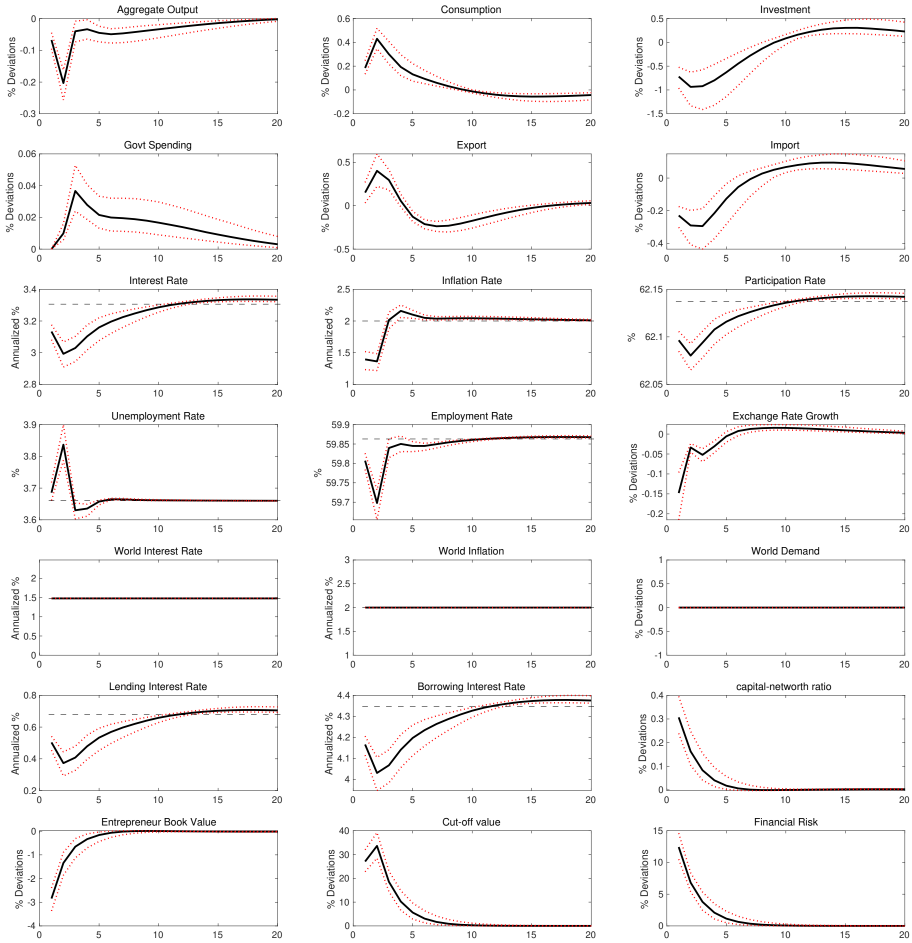
1. Black solid lines are posterior median IRFs.
   Red dotted lines are Bayesian credible intervals with lower bound, 10%, and upper bound, 90%.
   Black dashed lines are the steady state levels of selected variables; interest rates, inflation rates, and labor market indicators.
   Blue dash-dotted lines are IRFs of the New Keynesian model.
2. Units on y-axis may differ across variables: % is percentage in levels, % deviation is log-deviation from steady states and Annualized % is percentage per annum.

Figure 4: IRFs to foreign interest rate shock, $\varepsilon_t^{R_w}$



1. Black solid lines are posterior median IRFs.
   Red dotted lines are Bayesian credible intervals with lower bound, 10%, and upper bound, 90%.
   Black dashed lines are the steady state levels of selected variables; interest rates, inflation rates, and labor market indicators.
   Blue dash-dotted lines are IRFs of the New Keynesian model.
2. Units on y-axis may differ across variables: % is percentage in levels, % deviation is log-deviation from steady states and Annualized % is percentage per annum.

Figure 5: IRFs to financial risk shock, $\varepsilon_t^{\sigma_\omega}$



1. Black solid lines are posterior median IRFs.
   Red dotted lines are Bayesian credible intervals with lower bound, 10%, and upper bound, 90%.
   Black dashed lines are the steady state levels of selected variables; interest rates, inflation rates, and labor market indicators.
2. Units on y-axis may differ across variables: % is percentage in levels, % deviation is log-deviation from steady states and Annualized % is percentage per annum.

Table 8: Long-run variance decompositions

unit : %

	$\hat{y}_t^s$		$\hat{c}_t$		$\hat{i}_t$		R_t		Π_t		u_t^e		n_t^d		R_t^h	R_t^e
	FF	NK	FF	NK	FF	NK	FF	NK	FF	NK	FF	NK	FF	NK	FF	FF
ε^{υ}	4.82	8.55	12.93	23.23	11.51	2.95	53.31	52.35	26.19	32.24	21.22	25.23	5.61	10.28	38.65	42.88
ε^{φ}	32.84	14.82	19.84	5.93	4.65	0.65	4.94	8.20	2.39	5.13	4.01	6.10	47.25	27.36	3.33	3.67
ε^{ξ_i}	17.68	16.49	25.85	7.13	67.41	13.28	11.44	5.00	4.83	2.39	3.14	1.23	3.38	2.31	8.22	9.14
ε^{A}	26.26	11.19	17.22	7.83	1.19	0.20	10.38	10.87	16.54	17.08	22.68	26.56	15.76	24.50	7.30	8.11
ε^{m}	2.99	1.16	1.65	1.11	0.02	0.05	1.50	2.71	21.22	9.11	15.54	5.29	5.11	1.98	0.99	1.10
ε^{g}	0.21	0.31	0.35	0.18	0.02	0.00	0.18	0.18	0.33	0.29	0.54	0.57	0.36	0.53	0.12	0.14
ε^{R_w}	0.19	0.32	0.85	0.29	0.29	0.85	1.07	0.12	0.71	0.06	0.24	0.02	0.31	0.03	0.74	0.82
ε^{b_w}	1.49	8.15	3.69	9.62	0.80	1.73	5.66	1.66	5.45	7.12	2.80	16.90	2.47	13.69	3.87	4.30
ε^{y_W}	0.67	9.73	0.45	8.17	0.02	6.24	0.08	4.24	0.92	4.50	2.31	7.95	1.13	7.40	0.06	0.06
ε^{π_w}	2.86	25.02	1.81	32.49	0.05	73.98	0.14	9.09	4.11	6.94	10.68	5.03	4.89	5.15	0.10	0.11
ε^{μ}	5.63	4.26	4.37	4.02	0.71	0.06	2.28	5.57	9.55	15.14	11.81	5.12	8.77	6.76	1.38	1.54
$\varepsilon^{\sigma_\omega}$	3.54	-	9.59	-	9.31	-	8.26	-	7.21	-	4.23	-	4.39	-	5.82	6.48
ε^{ζ}	0.26	-	0.47	-	0.47	-	0.11	-	0.31	-	0.66	-	0.40	-	0.04	0.04
ε^{ξ_h}	0.28	-	0.44	-	1.56	-	0.26	-	0.07	-	0.02	-	0.05	-	29.10	4.80
ε^{ξ_e}	0.28	-	0.50	-	2.00	-	0.38	-	0.16	-	0.12	-	0.13	-	0.30	16.81

Note: FF is the financial friction model and NK is the New Keynesian model.

friction and New Keynesian models. First, domestic shocks, such as investment technology, TFP, and labor supply (intratemporal preference) shocks, are the main driving forces for the output fluctuations in the financial friction model. However, the foreign inflation rate shock was the largest factor for the output fluctuations in the New Keynesian model. This property is also consistent with consumption and investment. Moreover, the overall contributions of foreign shocks are moderated by other macroeconomic variables, such as the interest, inflation, unemployment, and employment rates. In addition, the financial risk shock rather has some contributions toward macroeconomic variables, while the three other financial shocks have negligible contributions.

The overall implied volatilities of these two models and those of the data are provided in Table 9. The fact that the implied volatilities of the financial friction model are closer to those of the data provides evidence that the financial friction model outperforms the New Keynesian model.

Table 9: Volatilities of the estimated models and data

Variables	Data	Estimated Model		Relative Ratio	
		FF	NK	FF	NK
$\hat{y}^s$	0.0114	0.0140	0.0160	1.2342	1.4099
$\hat{c}$	0.0187	0.0213	0.0283	1.1391	1.5135
$\hat{i}$	0.0249	0.0736	0.1323	2.9537	5.3110
$\hat{g}$	0.0092	0.0112	0.0112	1.2176	1.2178
$\hat{x}$	0.0431	0.0440	0.0770	1.0194	1.7871
R	0.0043	0.0049	0.0059	1.1356	1.3654
π	0.0045	0.0087	0.0113	1.9404	2.5246
u^e	0.0036	0.0092	0.0128	2.5834	3.6096
n^d	0.0073	0.0089	0.0102	1.2162	1.3920
R^w	0.0016	0.0036	0.0037	2.2439	2.3182
R^h	0.0049	0.0058	-	1.1795	-
R^e	0.0043	0.0056	-	1.3021	-

Note: 1) Volatilities are standard deviations of variables.
2) Estimated models are based on posterior modes of parameters.
3) Relative ratios are implied volatilities of models divided by volatilities of data
4) $\hat{X}$ is log-deviation of a variable X

3.5. HISTORICAL DECOMPOSITIONS

This subsection presents the historical decompositions and pays particular attention to the global financial crisis and the recent COVID-19 pandemic crisis. To obtain more comprehensible decomposition graphs, the shocks are grouped into six categories: aggregate demand, aggregate supply, policy, foreign, financial, and markup shocks.

Figure 6 shows the historical shock decompositions of GDP fluctuations. Overall, fluctuations in the GDP are driven by aggregate demand and supply shocks. Both shocks generated GDP contractions during the global financial crisis period from 2008 to 2009. Moreover, foreign shocks also had stronger negative effects on the GDP, reflecting the adverse external conditions during these periods. Meanwhile, the positive contributions of policy shocks seem to provide evidence of the implementation of expansionary policies in response to the crisis.

However, the aggregate supply shocks were the main driving forces during the pandemic crisis from 2020 to 2021. The aggregate demand shocks were rather tacit in 2020 and slowly recovered in 2021, dampening the adverse effects of the crisis. In addition, foreign shocks drastically generated short-lived GDP contraction in the second quarter of 2020. Expansionary policy responses were more pronounced in 2021. In sum, the global financial crisis and pandemic crisis somewhat differ in terms of the contributions of aggregate demand shocks.

Second, the shock decompositions of the unemployment rate are less apparent in making a robust assessment because the shocks' contributions are much less persistent, as shown in Figure 7. In addition, there is no clear distinction between these two crises in terms of their shock contributions. Rather, there is a similarity between these two crises, in which aggregate demand shocks and foreign shocks are the main causes of high unemployment in the early stages of these crises. In addition, the expansionary policy shocks are quite clear, as the unemployment rates are suppressed downward for some consecutive periods during both crises.

Finally, the shock decompositions of investment are examples with highly persistent contributions of shocks, which is in stark contrast to the case of the unemployment rate. During the normal periods of the mid-2010s, the aggregate demand shocks were the main driving forces for investment increase, while aggregate supply shocks were contractionary toward investment. Compared with the GDP and unemployment rates, investments are much more sensitive to financial shocks. In particular, the financial shocks were clearly adverse during the global financial crisis, although not as much during the pandemic. Another noticeable distinction between these two crises is that the contributions of the aggregate demand shocks are strongly negative during the global financial crisis and mostly positive during the pandemic crisis. This is consistent with the shock decomposition of the GDP. However, aggregate supply shocks were not the source of GDP contractions in the early stages of the global financial crisis. Nevertheless, eventually, a delayed investment response to adverse aggregate supply shocks was manifested. As for the pandemic crisis, aggregate supply shocks are the main drivers of investment contractions persistently, which is evident in Graph 8.

4. CONCLUSION

This study attempts to provide business cycle implications for the Korean economy by identifying linkages between macroeconomic, financial, and labor market variables in a unified framework. To this end, this study uses a DSGE model that has a financial accelerator mechanism and involuntary unemployment along with the common features of a small open economy and those of medium-scale New Keynesian models. The labor friction, which is often omitted in standard New Keynesian models, provides an opportunity to simultaneously analyze the rich dynamics of labor market indicators such as employment and unemployment rates. In addition, the fully specified model and the standard New Keynesian model are intensively compared to make better assessments of the performances and roles of financial friction when the Korean economy is introduced to the business cycle analysis through the lens of DSGE models. Lastly, this paper analyzes and compares two crisis episodes—the global financial crisis and the COVID-19 pandemic, using the historical shock decompositions of selected macroeconomic variables. The following is a summary of the overall assessment.

First, the financial friction model outperforms the New Keynesian model in terms of the implied volatilities of key macroeconomic variables. Second, the structural shocks in the financial friction model generally have more amplification effects on macroeconomic variables than in the New Keynesian model. Moreover, money non-neutrality was stronger, even with lower price and wage rigidities in the financial friction model. Third, the TFP shock induced not only an amplified response of output but also a similar response of investment. This result implies that the “Fisher deflationary effect,” which in general should have a dampening effect on investment, is not strong in the estimated model, probably due to low price rigidity. Rather, the export demand channel through the price competitiveness in the international market was amplified, leading to ex-

Figure 6: Historical shock decomposition of the GDP (HP Detrended)

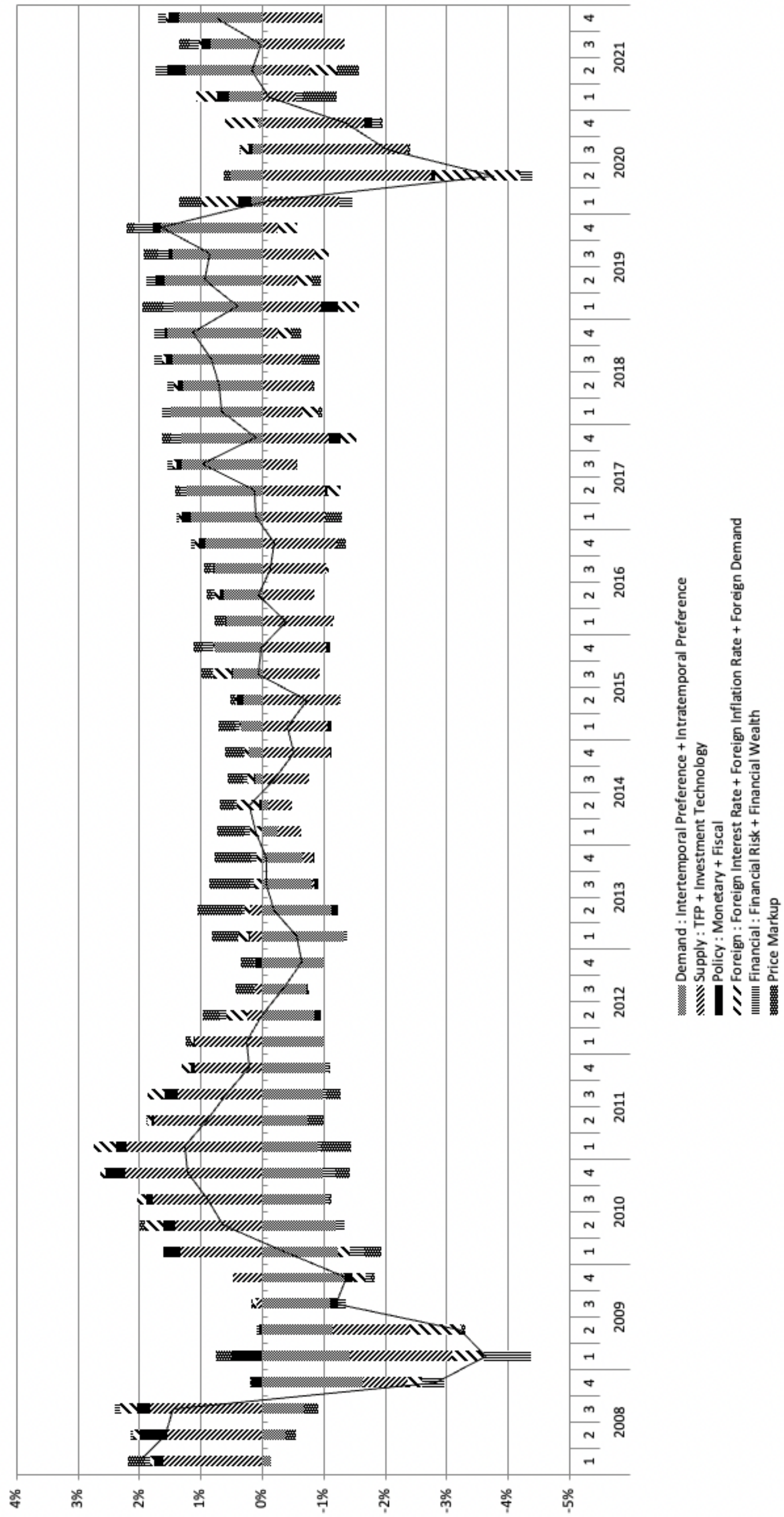
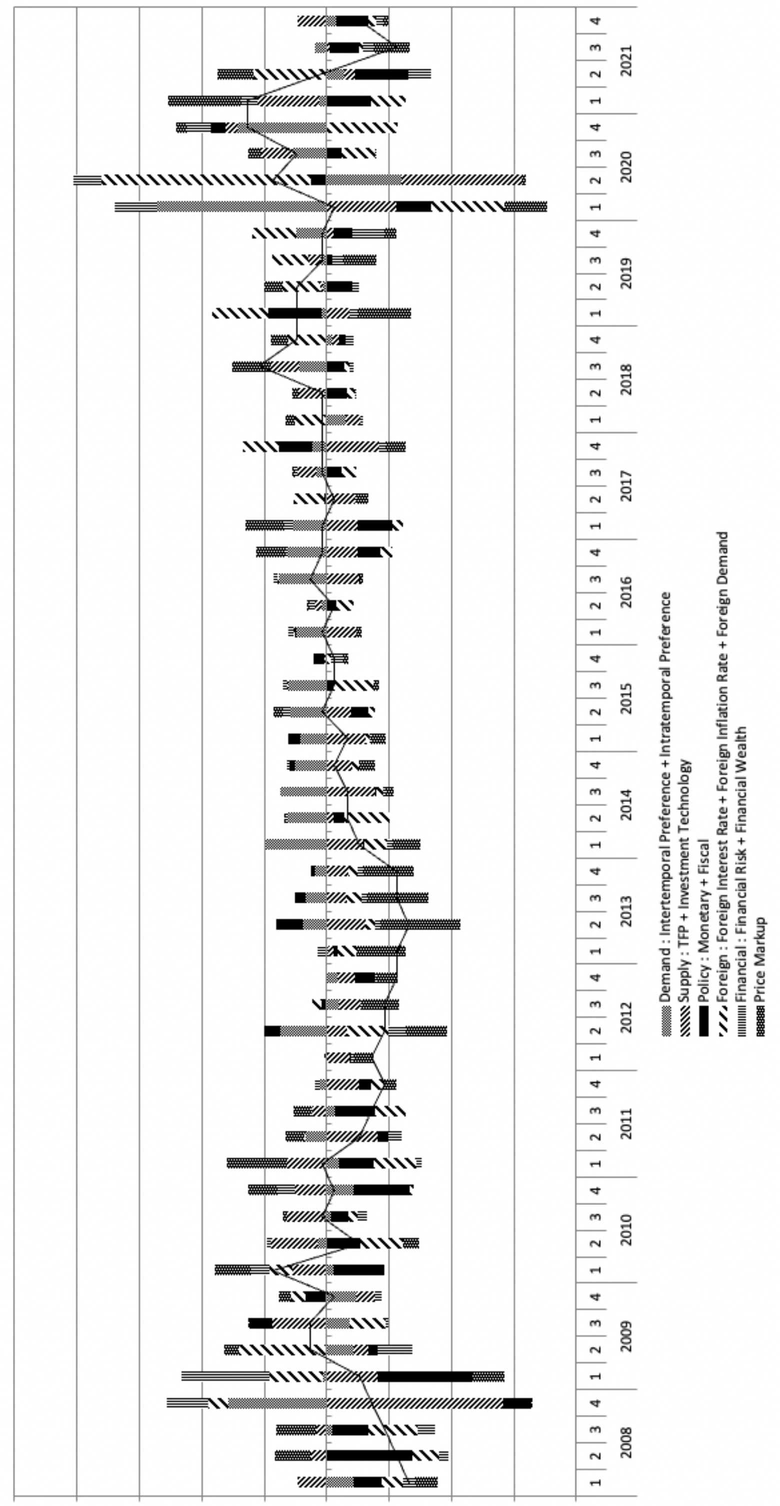


Figure 7: Historical shock decomposition of unemployment rate (Demeaned)



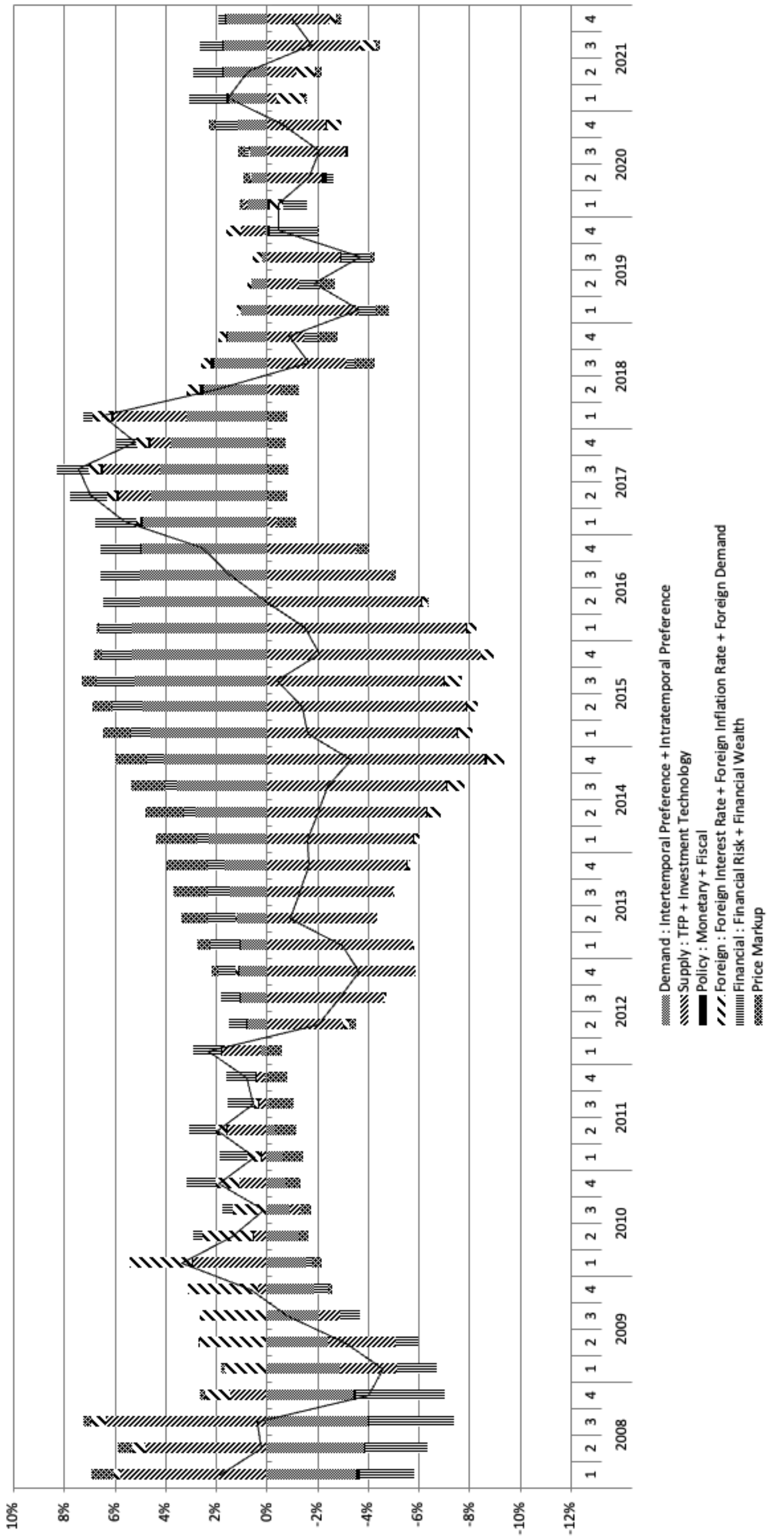


Figure 8: Historical shock decomposition of investment (HP Detrended)

pansionary investment and output. Fourth, the estimated financial friction model weighs relatively more to the domestic shocks' contributions toward the variance of macroeconomic variables and thus less to foreign shocks. This is in stark contrast to the New Keynesian model, in which foreign shock contributions are excessive. For instance, the foreign inflation shock in the estimated New Keynesian model constitutes an approximately 25% variability of the output and 75% variability of the investment.

Fifth, financial risk shocks have significant effects on investment in terms of variance decomposition. In addition, the historical shock decomposition of investment shows that the contraction of investment during the financial crisis is more or less caused by adverse financial shocks. Sixth, the historical shock decomposition of the output indicated that the global financial crisis was driven by aggregate demand, aggregate supply, and foreign shocks. However, the recent pandemic crisis was mostly driven by adverse aggregate supply shocks, while the adverse foreign shock contribution was short-lived. Seventh, policy shocks played important roles in dampening the adverse effects of shocks, especially on output and unemployment rate. However, policy shocks did not substantially promote investment during these crises.

The macroeconomic models developed so far have attempted to make rigorous assessments of past crisis episodes, so that more efficient policy responses can be implemented in future crises. The empirical analysis performed in this study presents historical evidence of the Korean economy using the most up-to-date DSGE model. The evidence in this paper should hopefully provide some guidelines for future extensions in terms of academic research and also for potential policy decisions in response to new challenges.

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Appendix.1. EQUILIBRIUM CONDITIONS

- Capital producers

$$k_t = (1-\delta)k_{t-1} + \xi_t^i\left(1 - S\left(\frac{i_t}{i_{t-1}}\right)\right)i_t \tag{A.1}$$

$$\frac{p_t^i}{p_t}\lambda_t = \lambda_t q_t \xi_t^i F_{1,t} + \beta\mathbb{E}_t\left[\lambda_{t+1}q_{t+1}\xi_{t+1}^i F_{2,t+1}\right] \tag{A.2}$$

- Entrepreneurs

$$r_{t+1}^k = \frac{\Phi'(u_{t+1})}{\xi_{t+1}^i(1-\tau_k)} \tag{A.3}$$

$$R_{t+1}^k = \Pi_{t+1}\frac{\left[u_{t+1}r_{t+1}^k(1-\tau_k) + (1-\delta)q_{t+1} - \frac{\Phi(u_{t+1})}{\xi_{t+1}^i} + \frac{\delta\tau_k}{\xi_{t+1}^i}\right]}{q_t} \tag{A.4}$$

$$\frac{d_t^e}{q_t k_t} = \left(\Gamma(\bar{\omega}_{t+1};\sigma_t^\omega) - \mu_e G(\bar{\omega}_{t+1};\sigma_t^\omega)\right)\frac{R_{t+1}^k}{R_t^e} \tag{A.5}$$

$$0 = \mathbb{E}_t\left\{[1-\Gamma(\cdot)]\frac{R_{t+1}^k}{R_t^e} + \frac{\Gamma_{\bar{\omega}}(\cdot)}{\Gamma_{\bar{\omega}}(\cdot) - \mu_e G_{\bar{\omega}}(\cdot)}\left[\frac{R_{t+1}^k}{R_t^e}\left(\Gamma(\cdot) - \mu_e G(\cdot)\right) - 1\right]\right\} \tag{A.6}$$

$$V_t = \left(R_t^k - R_{t-1}^e - \mu_e G\left(\omega_t;\sigma_{t-1}^\omega\right)R_t^k\right)\frac{q_{t-1}k_{t-1}}{\Pi_t} + \frac{R_{t-1}^e}{\Pi_t}nw_{t-1} \tag{A.7}$$

$$nw_t = \zeta_t V_t + W^e \tag{A.8}$$

$$(1+\tau_c)c_t^e = (1-\zeta_t)\gamma_e V_t \tag{A.9}$$

- Financial intermediaries

$$\Gamma_t^e = \beta\mathbb{E}_t\left[\frac{\lambda_{t+1}}{\lambda_t}\frac{1}{\Pi_{t+1}}R_t^e\right] \tag{A.10}$$

$$(1-\gamma_b)\Gamma_t^h = \beta\mathbb{E}_t\left[\frac{\lambda_{t+1}}{\lambda_t}\frac{1}{\Pi_{t+1}}R_t^h\right] \tag{A.11}$$

- Equilibrium conditions of the financial friction are from (A.4) to (A.11) in addition to (A.13). The standard New Keynesian model has the following condition instead of those of financial friction equilibrium conditions.

$$\lambda_t q_t = \beta \mathbb{E}_t \left\{ \lambda_{t+1} \left[u_{t+1} r^k_{t+1} (1-\tau_k) + (1-\delta) q_{t+1} - \frac{\Phi(u_{t+1})}{\xi^i_{t+1}} + \frac{\delta \tau_k}{\xi^i_{t+1}} \right] \right\}$$

- Households' equilibrium conditions except for labor-related variables

$$\lambda_t (1+\tau_c) \frac{p^c_t}{p_t} = \upsilon_t \left(c^h_t - \vartheta_c c^h_{t-1} \right)^{-1} - \vartheta_c \beta \mathbb{E}_t \upsilon_{t+1} \left(c^h_{t+1} - \vartheta_c c^h_t \right)^{-1} \tag{A.12}$$

$$\lambda_t = \psi_d \left(d^h_t \right)^{-\vartheta_d} + \beta \mathbb{E}_t \left[\lambda_{t+1} \frac{R^h_t}{\Pi_{t+1}} \right] \tag{A.13}$$

$$\lambda_t = \beta \mathbb{E}_t \left[\lambda_{t+1} \frac{R_t}{\Pi_{t+1}} \right] \tag{A.14}$$

$$\lambda_t = \beta \mathbb{E}_t \left[\lambda_{t+1} \frac{R^W_t \Gamma^W \left(ex_t \tilde{b}^W_t, \xi^{b^W}_t \right)}{\Pi_{t+1}} \frac{ex_{t+1}}{ex_t} \right] \tag{A.15}$$

- Households' equilibrium conditions for differentiated labor service

$$\Pi^{w^*}_t = \frac{w^*_t}{w_t} \tag{A.16}$$

$$f_t = \frac{\eta - 1}{\eta} (1-\tau_w) (w^*_t)^{1-\eta} \lambda_t w^\eta_t n^d_t + \beta \theta_w \mathbb{E}_t \left(\frac{\Pi^{\chi_w}_t}{\Pi_{t+1}} \right)^{1-\eta} \left(\frac{w^*_{t+1}}{w^*_t} \right)^{\eta-1} f_{t+1} \tag{A.17}$$

$$f_t = \psi_n d_t \varphi_t \left(\frac{w_t}{w^*_t} \right)^{\eta(1+\vartheta_n)} \left(n^d_t \right)^{1+\vartheta_n} + \beta \theta_w \mathbb{E}_t \left(\frac{\Pi^{\chi_w}_t}{\Pi_{t+1}} \right)^{-\eta(1+\vartheta_n)} \left(\frac{w^*_{t+1}}{w^*_t} \right)^{\eta(1+\vartheta_n)} f_{t+1} \tag{A.18}$$

- Domestic intermediate goods producers

$$\frac{u_t k_{t-1}}{n_t^d} = \frac{\alpha}{1-\alpha}\frac{w_t}{r_t^k} \tag{A.19}$$

$$mc_t = \left(\frac{1}{1-\alpha}\right)^{1-\alpha}\left(\frac{1}{\alpha}\right)^{\alpha}\frac{w_t^{1-\alpha}\left(r_t^k\right)^{\alpha}}{A_t} \tag{A.20}$$

$$g_t^1 = \lambda_t mc_t y_t^d + \beta\theta_p \mathbb{E}_t\left(\frac{\Pi_t^{\chi}}{\Pi_{t+1}}\right)^{-\varepsilon} g_{t+1}^1 \tag{A.21}$$

$$g_t^2 = \lambda_t \Pi_t^* y_t^d + \beta\theta_p \mathbb{E}_t\left(\frac{\Pi_t^{\chi}}{\Pi_{t+1}}\right)^{1-\varepsilon}\left(\frac{\Pi_t^*}{\Pi_{t+1}^*}\right) g_{t+1}^2 \tag{A.22}$$

$$\varepsilon g_t^1 = (\varepsilon-1)\, g_t^2 \tag{A.23}$$

- Composite consumption goods and investment goods

$$c_t = \left[(n^c)^{\frac{1}{\varepsilon_c}}\left(c_t^d\right)^{\frac{\varepsilon_c-1}{\varepsilon_c}} + (1-n^c)^{\frac{1}{\varepsilon_c}}\left(c_t^M\left(1-\Gamma_t^c\right)\right)^{\frac{\varepsilon_c-1}{\varepsilon_c}}\right]^{\frac{\varepsilon_c}{\varepsilon_c-1}} \tag{A.24}$$

$$i_t = \left[\left(n^i\right)^{\frac{1}{\varepsilon_i}}\left(i_t^d\right)^{\frac{\varepsilon_i-1}{\varepsilon_i}} + \left(1-n^i\right)^{\frac{1}{\varepsilon_i}}\left(i_t^M\left(1-\Gamma_t^i\right)\right)^{\frac{\varepsilon_i-1}{\varepsilon_i}}\right]^{\frac{\varepsilon_i}{\varepsilon_i-1}} \tag{A.25}$$

The import cost functions, Γ_t^c and Γ_t^i, are assumed. This specification is a friction that prevents the excess volatilities of imported goods.

- Demand functions for import and export

$$c_t^M = \mathbb{E}_t\Omega_{t+1}^c (1-n^c)\left(\frac{p_t^M}{p_t^c}\right)^{-\varepsilon_c} c_t \tag{A.26}$$

$$i_t^M = \mathbb{E}_t\Omega_{t+1}^i \left(1-n^i\right)\left(\frac{p_t^M}{p_t^i}\right)^{-\varepsilon_i} i_t \tag{A.27}$$

$$x_t = v_t^x\left(\frac{p_t^x}{p_t^W}\right)^{-\varepsilon_W} y_t^W \tag{A.28}$$

$$y_t^x = \left(\frac{p_t^x}{p_t^W}\right)^{-\varepsilon_W} y_t^W \tag{A.29}$$

Ω_t^c and Ω_t^i are results of derivatives of the import cost functions, Γ_t^c와 Γ_t^i.

$$\mathbb{E}_t\Omega_{t+1}^c = \frac{\left[1-\beta\left(1-n^c\right)^{\frac{1}{\varepsilon_c}}\mathbb{E}_t\frac{\lambda_{t+1}}{\lambda_t}\left(\frac{p_t^c}{p_t^M}\right)\Pi_{t+1}^c\left(\frac{c_{t+1}}{c_{t+1}^M\left(1-\Gamma_{t+1}^c\right)}\right)^{\frac{1}{\varepsilon_c}}\Gamma_{t+1}^{c\prime}\frac{\left(\Delta c_{t+1}^M\right)^2}{\Delta c_{t+1}}\right]^{-\varepsilon_c}}{\left(1-\Gamma_t^c\right)\left[1-\Gamma_t^c-\Gamma_t^{c\prime}\left(\frac{\Delta c_t^M}{\Delta c_t}\right)\right]^{-\varepsilon_c}} \tag{A.30}$$

$$\mathbb{E}_t\Omega_{t+1}^i = \frac{\left[1-\beta\left(1-n^i\right)^{\frac{1}{\varepsilon_i}}\mathbb{E}_t\frac{\lambda_{t+1}}{\lambda_t}\left(\frac{p_t^i}{p_t^M}\right)\Pi_{t+1}^i\left(\frac{i_{t+1}}{i_{t+1}^M\left(1-\Gamma_{t+1}^i\right)}\right)^{\frac{1}{\varepsilon_i}}\Gamma_{t+1}^{i\prime}\frac{\left(\Delta i_{t+1}^M\right)^2}{\Delta i_{t+1}}\right]^{-\varepsilon_i}}{\left(1-\Gamma_t^i\right)\left[1-\Gamma_t^i-\Gamma_t^{i\prime}\left(\frac{\Delta i_t^M}{\Delta i_t}\right)\right]^{-\varepsilon_i}} \tag{A.31}$$

- Export and import distributors

$$g_t^{M_1} = \lambda_t mc_t^M y_t^M + \beta\theta_M\mathbb{E}_t\left(\frac{\left(\Pi_t^M\right)^{\chi_M}}{\Pi_{t+1}^M}\right)^{-\varepsilon_M} g_{t+1}^{M_1} \tag{A.32}$$

$$g_t^{M_2} = \lambda_t\Pi_t^{M^*} y_t^M + \beta\theta_M\mathbb{E}_t\left(\frac{\left(\Pi_t^M\right)^{\chi_M}}{\Pi_{t+1}^M}\right)^{1-\varepsilon_M}\left(\frac{\Pi_t^{M^*}}{\Pi_{t+1}^{M^*}}\right) g_{t+1}^{M_2} \tag{A.33}$$

$$g_t^{x_1} = \lambda_t mc_t^x y_t^x + \beta\theta_x\mathbb{E}_t\left(\frac{\left(\Pi_t^W\right)^{\chi_x}}{\Pi_{t+1}^x}\right)^{-\varepsilon_x} g_{t+1}^{x_1} \tag{A.34}$$

$$g_t^{x_2} = \lambda_t\Pi_t^{x^*} y_t^x + \beta\theta_x\mathbb{E}_t\left(\frac{\left(\Pi_t^W\right)^{\chi_x}}{\Pi_{t+1}^x}\right)^{1-\varepsilon_x}\left(\frac{\Pi_t^{x^*}}{\Pi_{t+1}^{x^*}}\right) g_{t+1}^{x_2} \tag{A.35}$$

$$\varepsilon_M g_t^{M_1} = \left(\varepsilon_M-1\right) g_t^{M_2} \tag{A.36}$$

$$\varepsilon_x g_t^{x_1} = \left(\varepsilon_x-1\right) g_t^{x_2} \tag{A.37}$$

$$mc_t^M = \frac{p_t^W ex_t}{p_t^M} \tag{A.38}$$

$$mc_t^x = \frac{p_t}{ex_t p_t^x} \tag{A.39}$$

- Taylor rule by monetary authority

$$\hat{R}_t = \gamma_R\hat{R}_{t-1} + \left(1-\gamma_R\right)\left(\gamma_\Pi\hat{\Pi}_t + \gamma_y\hat{y}_{t-1}^s + \gamma_{ex}\log\left(\frac{ex_t}{ex_{t-1}}\right)\right) + \sigma_m\varepsilon_{m,t} \tag{A.40}$$

$\hat{X}$ implies the log-deviation of X from its own steady state.

- Government budget and long-run fiscal balance

$$\begin{aligned}\tilde{b}_t &= \frac{g_t}{y_t^d} + \frac{T_t^g}{y_t^d} + \frac{R_{t-1}\tilde{b}_{t-1}y_{t-1}^d}{y_t^d \Pi_t} \\ &\quad - \left(r_t^k u_t - \frac{1}{\xi_t^i}\delta \right) \tau_k \frac{k_{t-1}}{y_t^d} - \tau_w w_t \frac{n_t^d}{y_t^d} - \tau_c \frac{p_t^c}{p_t}\frac{c_t}{y_t^d}\end{aligned} \tag{A.41}$$

$$\frac{T_t^g}{y_t^d} = T_0 - T_1 \left(\tilde{b}_t - \overline{\tilde{b}} \right) \tag{A.42}$$

- Balance of payments

$$\begin{aligned}ex_t\tilde{b}_t^W &= R_{t-1}^W \Gamma \left(ex_t \tilde{b}_{t-1}^W, \xi_{t-1}^{b^W} \right) ex_t \tilde{b}_{t-1}^W \frac{y_{t-1}^d}{\Pi_t y_t^d} \\ &\quad + ex_t \frac{p_t^x}{p_t y_t^d} \left(\frac{p_t^x}{p_t^W} \right)^{-\varepsilon_W} y_t^W - ex_t \frac{p_t^W M_t}{p_t y_t^d}\end{aligned} \tag{A.43}$$

- Market clearing conditions

$$\begin{aligned}y_t^d &= n^c \left(\frac{p_t}{p_t^c} \right)^{-\varepsilon_c} c_t + n^i \left(\frac{p_t}{p_t^i} \right)^{-\varepsilon_i} i_t + g_t \\ &\quad + \frac{1}{\xi_t^i} \Phi [u_t] k_{t-1} + \frac{\mu_e G_{t-1}(\bar{\omega}_t) R_t^k q_{t-1} k_{t-1}}{\Pi_t} + x_t\end{aligned} \tag{A.44}$$

$$y_t^s = A_t (u_t k_{t-1})^{\alpha} \left(n_t^d \right)^{1-\alpha} - \phi \tag{A.45}$$

$$y_t^s = v_t^P y_t^d \tag{A.46}$$

$$c_t = c_t^h + c_t^e \tag{A.47}$$

$$y_t^M = c_t^M + i_t^M \tag{A.48}$$

$$M_t = v_t^M \left[(1 - n^c) \left(\frac{p_t^M}{p_t^c} \right)^{-\varepsilon_c} c_t + \left(1 - n^i \right) \left(\frac{p_t^M}{p_t^i} \right)^{-\varepsilon_i} i_t \right] \tag{A.49}$$

- Labor market-related variables

$$\ell_t^s = \left(\frac{\lambda_t(1-\tau_w)}{d_t\varphi_t\psi_n}\right)^{\frac{1}{\vartheta_n}}\left(w_t^L\right)^{\frac{1}{\vartheta_n}} \tag{A.50}$$

$$\left(w_t^L\right)^{\frac{1}{\vartheta_n}} = (1-\theta_w)\left(w_t^*\right)^{\frac{1}{\vartheta_n}} + \theta_w\left(\frac{\Pi_{t-1}^{\chi_w}}{\Pi_t}\right)^{\frac{1}{\vartheta_n}}\left(w_{t-1}^L\right)^{\frac{1}{\vartheta_n}} \tag{A.51}$$

$$u_t^e = 1-\frac{n_t^d}{\ell_t^s} \tag{A.52}$$

- Various price and wage inflation rate processes

$$1 = \theta_p\left(\frac{\Pi_{t-1}^{\chi}}{\Pi_t}\right)^{1-\varepsilon} + (1-\theta_p)\Pi_t^{*1-\varepsilon} \tag{A.53}$$

$$1 = \theta_w\left(\frac{\Pi_{t-1}^{\chi_w}}{\Pi_t}\right)^{1-\eta}\left(\frac{w_{t-1}}{w_t}\right)^{1-\eta} + (1-\theta_w)\left(\Pi_t^{w^*}\right)^{1-\eta} \tag{A.54}$$

$$1 = \theta_M\left(\frac{\left(\Pi_{t-1}^M\right)^{\chi_M}}{\Pi_t^M}\right)^{1-\varepsilon_M} + (1-\theta_M)\left(\Pi_t^{M^*}\right)^{1-\varepsilon_M} \tag{A.55}$$

$$1 = \theta_x\left(\frac{\left(\Pi_{t-1}^W\right)^{\chi_x}}{\Pi_t^x}\right)^{1-\varepsilon_x} + (1-\theta_x)\left(\Pi_t^{x^*}\right)^{1-\varepsilon_x} \tag{A.56}$$

- Various price and wage dispersions

$$v_t^p = \theta_p\left(\frac{\Pi_{t-1}^{\chi}}{\Pi_t}\right)^{-\varepsilon} v_{t-1}^p + (1-\theta_p)\Pi_t^{*-\varepsilon} \tag{A.57}$$

$$v_t^M = \theta_M\left(\frac{\left(\Pi_{t-1}^M\right)^{\chi_M}}{\Pi_t^M}\right)^{-\varepsilon_M} v_{t-1}^M + (1-\theta_M)\left(\Pi_t^{M^*}\right)^{-\varepsilon_M} \tag{A.58}$$

$$v_t^x = \theta_x\left(\frac{\left(\Pi_{t-1}^W\right)^{\chi_x}}{\Pi_t^x}\right)^{-\varepsilon_x} v_{t-1}^x + (1-\theta_x)\left(\Pi_t^{x^*}\right)^{-\varepsilon_x} \tag{A.59}$$

$$v_t^w = \theta_w\left(\frac{\Pi_{t-1}^{\chi_w}}{\Pi_t}\frac{w_{t-1}}{w_t}\right)^{-\eta} v_{t-1}^w + (1-\theta_w)\left(\Pi_t^{w^*}\right)^{-\eta} \tag{A.60}$$

- Prices of composites

$$p_t^c = \left[n^c (p_t)^{1-\varepsilon_c} + \mathbb{E}_t \Omega_{t+1}^c (1-n^c) \left(p_t^M\right)^{1-\varepsilon_c}\right]^{\frac{1}{1-\varepsilon_c}} \tag{A.61}$$

$$p_t^i = \left[n^i (p_t)^{1-\varepsilon_i} + \mathbb{E}_t \Omega_{t+1}^i \left(1-n^i\right) \left(p_t^M\right)^{1-\varepsilon_i}\right]^{\frac{1}{1-\varepsilon_i}} \tag{A.62}$$

- Definitions of various inflation rates

$$\Pi_t = \frac{p_t}{p_{t-1}}$$

$$\Pi_t^c = \frac{\left(\frac{p_t^c}{p_t}\right)}{\left(\frac{p_{t-1}^c}{p_{t-1}}\right)} \Pi_t$$

$$\Pi_t^i = \frac{\left(\frac{p_t^i}{p_t}\right)}{\left(\frac{p_{t-1}^i}{p_{t-1}}\right)} \Pi_t$$

$$\Pi_t^M = \frac{\left(\frac{p_t^M}{p_t}\right)}{\left(\frac{p_{t-1}^M}{p_{t-1}}\right)} \Pi_t$$

$$\Pi_t^x = \frac{\left(\frac{ex_t p_t^x}{p_t}\right)}{\left(\frac{ex_{t-1} p_{t-1}^x}{p_{t-1}}\right)} \frac{\Pi_t}{\Delta ex_t}$$

$$\Pi_t^W = \frac{\left(\frac{ex_t p_t^W}{p_t}\right)}{\left(\frac{ex_{t-1} p_{t-1}^W}{p_{t-1}}\right)} \frac{\Pi_t}{\Delta ex_t}$$

- Structural shocks of the model

$$
\begin{aligned}
\text{Total factor productivity}: \quad & \log A_t && = \rho_A \log A_{t-1} + \sigma_A \varepsilon_t^A \\
\text{Investment technology}: \quad & \log \xi_t^i && = \rho_{\xi_i} \log \xi_{t-1}^i + \sigma_{\xi_i} \varepsilon_t^{\xi_i} \\
\text{Inter-temporal preference}: \quad & \log \upsilon_t && = \rho_\upsilon \log \upsilon_{t-1} + \sigma_\upsilon \varepsilon_t^\upsilon \\
\text{Labor supply preference}: \quad & \log \varphi_t && = \rho_\varphi \log \varphi_{t-1} + \sigma_\varphi \varepsilon_t^\varphi \\
\text{Government spending}: \quad & \hat{g}_t && = \rho_g \hat{g}_{t-1} + (1-\rho_g)\gamma_{g_y} \hat{y}_{t-1}^s + \sigma_g \varepsilon_t^g \\
\text{Country risk premium}: \quad & \xi_t^{b^W} && = \rho_{b_w} \xi_{t-1}^{b^W} + \sigma_{b_w} \varepsilon_t^{b_w} \\
\text{Foreign demand}: \quad & \hat{y}_t^W && = \rho_{y_w} \hat{y}_{t-1}^W + \sigma_{y_w} \varepsilon_t^{y_w} + \sigma_{y,\pi} \tilde{\varepsilon}_t^{\pi_w} \\
\text{Foreign inflation}: \quad & \hat{\Pi}_t^W && = \rho_{\pi_w} \hat{\Pi}_{t-1}^W + \sigma_{\pi_w} \varepsilon_t^{\pi_w} + \sigma_{\pi,y} \tilde{\varepsilon}_t^{y_w} \\
\text{Foreign interest rate}: \quad & \hat{R}_t^W && = \rho_{R_w} \hat{R}_{t-1}^W + \sigma_{R_w} \varepsilon_t^{R_w} + \sigma_{R,y} \tilde{\varepsilon}_t^{y_w} + \sigma_{R,\pi} \tilde{\varepsilon}_t^{\pi_w} \\
\text{Markup for domestic good}: \quad & \hat{\mu}_t && = \rho_{\mu_d} \hat{\mu}_{t-1} + \sigma_{\mu_d} \varepsilon_t^\mu \\
\text{Financial risk}: \quad & \hat{\sigma}_t^\omega && = \rho_{\sigma_\omega} \hat{\sigma}_{t-1}^\omega + \sigma_{\sigma_\omega} \varepsilon_t^{\sigma_\omega} \\
\text{Financial wealth}: \quad & \tilde{\zeta}_t^e && = \rho_\zeta \tilde{\zeta}_{t-1}^e + \sigma_\zeta \varepsilon_t^\zeta \\
\text{Loan interest rate}: \quad & \xi_t^e && = \rho_{\xi_e} \xi_{t-1}^e + \sigma_{\xi_e} \left(\varepsilon_t^{\xi_e} + \mu_{\xi_e} \varepsilon_{t-1}^{\xi_e} \right) \\
\text{Deposit interest rate}: \quad & \xi_t^h && = \rho_{\xi_h} \xi_{t-1}^h + \sigma_{\xi_h} \left(\varepsilon_t^{\xi_h} + \mu_{\xi_h} \varepsilon_{t-1}^{\xi_h} \right)
\end{aligned}
$$

  - Financial risk shock is the shock to the volatility of the entrepreneurs' idiosyncratic productivities.
  - Financial wealth shock is the shock that is associated with the entrepreneurs' survival probability.
  - Markup for domestic goods can be related to the substitution elasticity between the domestic intermediate goods, ε, as follows:

$$\mu_t \equiv \frac{\varepsilon_t}{\varepsilon_t - 1}$$

- Various functional forms assumed in the model

  1. Capital utilization cost

$$\Phi[u] = \Phi_1 (u-1) + \Phi_2 (u-1)^2 \tag{F.1}$$

  2. Investment Adjustment Cost

$$S\left(\frac{i_t}{i_{t-1}}\right) = \frac{\kappa}{2}\left(\frac{i_t}{i_{t-1}} - 1\right)^2 \tag{F.2}$$

Define

$$F\left(i_t, i_{t-1}\right) \equiv \left(1 - S\left(\frac{i_t}{i_{t-1}}\right)\right) i_t .$$

The partial derivatives associated with the above function

$$\begin{aligned} F_{1t} &= 1 - S\left(\frac{i_t}{i_{t-1}}\right) - S'\left(\frac{i_t}{i_{t-1}}\right)\frac{i_t}{i_{t-1}} \\ F_{2t+1} &= S'\left(\frac{i_{t+1}}{i_t}\right)\left(\frac{i_{t+1}}{i_t}\right)^2 \end{aligned}$$

3. Cost functions for the financial intermediary

$$\Gamma_t^e = \exp\left(\Gamma^{e_0} - \Gamma^{e_1}\left(\frac{\tilde{d}_t^h}{d_t^e} - \frac{\bar{d}^h}{\bar{d}^e}\right) + \xi_t^e\right)$$
$$\Gamma_t^h = \exp\left(\Gamma^{h_0} - \Gamma^{h_1}\left(\frac{\tilde{d}_t^h}{d_t^e} - \frac{\bar{d}^h}{\bar{d}^e}\right) + \xi_t^h\right)$$

4. Imported consumption and investment goods cost functions

$$\Gamma_t^s = \frac{\Gamma^s}{2}\left(\frac{s_t^M}{s_t} / \frac{s_{t-1}^M}{s_{t-1}} - 1\right)^2 \quad \text{for } s = c, i$$

Its derivative

$$\Gamma_t^{s'} = \Gamma^s\left(\frac{s_t^M}{s_t} / \frac{s_{t-1}^M}{s_{t-1}} - 1\right) \quad \text{for } s = c, i$$

5. Country risk premium

$$\Gamma^W\left(ex_t \tilde{b}_t^W, \xi_t^{b^W}\right) = \exp\left(\Gamma^{R_0^W} - \Gamma^{b^W}\left(ex_t \tilde{b}_t^W - ex\tilde{b}^W\right) + \xi_t^{b^W}\right) \quad \text{(F.3)}$$

Appendix.2. LINEARIZATION OF EQUILIBRIUM CONDITIONS WITH INTEGRATION

The financial accelerator model that is specified in this study has integrals associated with the density functions of the idiosyncratic productivities of entrepreneurs, which is a time-consuming computation when the software package solves with its own function. Hence, the linearized equations are derived manually for equilibrium conditions that involve integrals with finite boundaries, such as cut-off values. Hence, linearization of the equilibrium conditions, (A.5), (A.6), (A.7), and (A.44), is shown below.

- Some density functions associated with the idiosyncratic productivity, ω, that follows the log-normal probability are illustrated.

$$\begin{aligned}
F(\omega;\sigma) &: \text{ CDF of log-normal density} \\
& \quad\ \text{whose mean is } -\frac{1}{2}\sigma^2 \text{ and standard deviation } \sigma \\
f(\omega;\sigma) &: \text{ PDF of log-normal density} \\
\tilde{\mu}\left(\bar{\omega}_{t+1},\sigma_t^{\omega}\right) &\equiv \frac{\frac{1}{2}\left(\sigma_t^{\omega}\right)^2-\log\left(\bar{\omega}_{t+1}\right)}{\sigma_t^{\omega}} \\
\Phi(\tilde{\mu}) &: \text{ CDF of standard normal density} \\
\phi(\tilde{\mu}) &: \text{ PDF of standard normal density}
\end{aligned}$$

- Necessary function forms from equilibrium conditions of entrepreneurs

$$G\left(\bar{\omega}_{t+1},\sigma_t^{\omega}\right) \equiv 1-\Phi\left(\tilde{\mu}\left(\bar{\omega}_{t+1},\sigma_t^{\omega}\right)\right) \tag{P.1}$$

$$\Gamma\left(\bar{\omega}_{t+1},\sigma_t^{\omega}\right) \equiv \bar{\omega}_{t+1}\left[1-F\left(\bar{\omega}_{t+1},\sigma_t^{\omega}\right)\right]+G\left(\bar{\omega}_{t+1},\sigma_t^{\omega}\right) \tag{P.2}$$

- First derivatives of the two above-mentioned functions, (P.1) and (P.2)

$$\begin{aligned}
G_{\bar{\omega}}\left(\bar{\omega}_{t+1},\sigma_t^{\omega}\right) &= -\phi\left(\tilde{\mu}_t\right)\tilde{\mu}_{\bar{\omega},t}=\bar{\omega}_{t+1}f\left(\bar{\omega}_{t+1},\sigma_t^{\omega}\right) \\
\Gamma_{\bar{\omega}}\left(\bar{\omega}_{t+1},\sigma_t^{\omega}\right) &= 1-F\left(\bar{\omega}_{t+1},\sigma_t^{\omega}\right) \\
G_{\sigma^{\omega}}\left(\bar{\omega}_{t+1},\sigma_t^{\omega}\right) &= -\phi\left(\tilde{\mu}_t\right)\tilde{\mu}_{\sigma^{\omega},t} \\
\Gamma_{\sigma^{\omega}}\left(\bar{\omega}_{t+1},\sigma_t^{\omega}\right) &= -\bar{\omega}_{t+1}F_{\sigma^{\omega}}\left(\bar{\omega}_{t+1},\sigma_t^{\omega}\right)+G_{\sigma^{\omega}}\left(\bar{\omega}_{t+1},\sigma_t^{\omega}\right) \\
\tilde{\mu}_{\bar{\omega},t} &= -\frac{1}{\bar{\omega}_{t+1}\sigma_t^{\omega}} \\
\tilde{\mu}_{\sigma^{\omega},t} &= \frac{1}{2}+\frac{\log\left(\bar{\omega}_{t+1}\right)}{\left(\sigma_t^{\omega}\right)^2}
\end{aligned}$$

- Explicit form of the log-normal probability density function and its derivatives

$$
\begin{aligned}
F\left(x,\sigma_t^{\omega}\right) &= \int_0^{\bar{\omega}_t} \frac{1}{x\sigma_t^{\omega}\sqrt{2\pi}} \exp\left(-\frac{\left(\log\left(x\right)+\frac{1}{2}\left(\sigma_t^{\omega}\right)^2\right)^2}{2\left(\sigma_t^{\omega}\right)^2}\right) dx \\
F_{\bar{\omega}}\left(\bar{\omega}_{t+1},\sigma_t^{\omega}\right) &= f\left(\bar{\omega}_{t+1},\sigma_t^{\omega}\right) \\
F_{\bar{\omega}\bar{\omega}}\left(\bar{\omega}_{t+1},\sigma_t^{\omega}\right) &= f_{\bar{\omega}}\left(\bar{\omega}_{t+1},\sigma_t^{\omega}\right) \\
F_{\sigma^{\omega}}\left(\bar{\omega}_{t+1},\sigma_t^{\omega}\right) &= f\left(\bar{\omega}_{t+1},\sigma_t^{\omega}\right) f_{\sigma^{\omega}}\left(\bar{\omega}_{t+1},\sigma_t^{\omega}\right) \\
F_{\bar{\omega}\sigma^{\omega}}\left(\bar{\omega}_{t+1},\sigma_t^{\omega}\right) &= f_{\sigma^{\omega}}\left(\bar{\omega}_{t+1},\sigma_t^{\omega}\right) \\
f_{\bar{\omega}}\left(\bar{\omega}_{t+1},\sigma_t^{\omega}\right) &= f_t\left(\bar{\omega}_{t+1},\sigma_t^{\omega}\right)\left(-\frac{1}{\sigma_t^{\omega}}-\frac{\left(\log\left(\bar{\omega}_{t+1}\right)+\frac{1}{2}\left(\sigma_t^{\omega}\right)^2\right)}{\bar{\omega}_{t+1}\left(\sigma_t^{\omega}\right)^2}\right) \\
f_{\sigma^{\omega}}\left(\bar{\omega}_{t+1},\sigma_t^{\omega}\right) &= f\left(\cdot\right)\left(-\frac{1}{\sigma_t^{\omega}}+\frac{1}{\sigma_t^{\omega}}\left[\left(\frac{\log\bar{\omega}_{t+1}}{\sigma_t^{\omega}}\right)^2-\frac{1}{4}\left(\sigma_t^{\omega}\right)^2\right]\right)
\end{aligned}
$$

- Redefining the terms involving density functions

$$
\begin{aligned}
\Theta^A\left(\bar{\omega}_{t+1},\sigma_t^{\omega}\right) &\equiv \Gamma\left(\bar{\omega}_{t+1},\sigma_t^{\omega}\right)-\mu_e G\left(\bar{\omega}_{t+1},\sigma_t^{\omega}\right) \\
\Theta^B\left(\bar{\omega}_{t+1},\sigma_t^{\omega}\right) &\equiv 1-\Gamma\left(\bar{\omega}_{t+1},\sigma_t^{\omega}\right) \\
\Theta^C\left(\bar{\omega}_{t+1},\sigma_t^{\omega}\right) &\equiv \frac{\Gamma_{\bar{\omega}}\left(\bar{\omega}_{t+1},\sigma_t^{\omega}\right)}{\Gamma_{\bar{\omega}}\left(\bar{\omega}_{t+1},\sigma_t^{\omega}\right)-\mu_e G_{\bar{\omega}}\left(\bar{\omega}_{t+1},\sigma_t^{\omega}\right)} \\
\Theta^D\left(\bar{\omega}_t,\sigma_{t-1}^{\omega}\right) &\equiv \mu_e G\left(\bar{\omega}_t,\sigma_{t-1}^{\omega}\right)
\end{aligned}
$$

- Equilibrium conditions with redefinitions,

$$
\begin{aligned}
\frac{d_t^e}{q_t k_t} &= \Theta^A\left(\bar{\omega}_{t+1},\sigma_t^{\omega}\right)\frac{R_{t+1}^k}{R_t^e} \\
0 &= \mathbb{E}_t\left\{\Theta^B\left(\bar{\omega}_{t+1},\sigma_t^{\omega}\right)\frac{R_{t+1}^k}{R_t^e}-\Theta^C\left(\bar{\omega}_{t+1},\sigma_t^{\omega}\right)\frac{nw_t}{q_t k_t}\right\} \\
V_t &= \left(1-\Theta^D\left(\bar{\omega}_t,\sigma_{t-1}^{\omega}\right)\right)\frac{R_t^k}{\Pi_t}q_{t-1}k_{t-1}-\frac{R_{t-1}^e}{\Pi_t}d_{t-1}^e \\
y_t^d &= c_t^d+i_t^d+g_t+\frac{1}{\xi_t^i}\Phi\left[u_t\right]k_{t-1}+\frac{\Theta^D\left(\bar{\omega}_t,\sigma_{t-1}^{\omega}\right)R_t^k q_{t-1}k_{t-1}}{\Pi_t}+x_t
\end{aligned}
$$

- Linearizing the equilibrium conditions

$$
\begin{aligned}
\hat{d}_t^e - \hat{q}_t - \hat{k}_t &= \hat{R}_{t+1}^k - \hat{R}_t^e + \frac{\Theta_{\bar{\omega}}^A\left(\bar{\omega},\sigma^{\omega}\right)}{\Theta^A\left(\bar{\omega},\sigma^{\omega}\right)}\bar{\omega}\hat{\bar{\omega}}_{t+1} + \frac{\Theta_{\sigma^{\omega}}^A\left(\bar{\omega},\sigma^{\omega}\right)}{\Theta^A\left(\bar{\omega},\sigma^{\omega}\right)}\sigma^{\omega}\hat{\sigma}_t^{\omega} \\
\hat{R}_{t+1}^k - \hat{R}_t^e &+ \frac{\Theta_{\bar{\omega}}^B\left(\bar{\omega},\sigma^{\omega}\right)}{\Theta^B\left(\bar{\omega},\sigma^{\omega}\right)}\bar{\omega}\hat{\bar{\omega}}_{t+1} + \frac{\Theta_{\sigma^{\omega}}^B\left(\bar{\omega},\sigma^{\omega}\right)}{\Theta^B\left(\bar{\omega},\sigma^{\omega}\right)}\sigma^{\omega}\hat{\sigma}_t^{\omega} \\
&= n\hat{w}_t - \hat{q}_t - \hat{k}_t + \frac{\Theta_{\bar{\omega}}^C\left(\bar{\omega},\sigma^{\omega}\right)}{\Theta^C\left(\bar{\omega},\sigma^{\omega}\right)}\bar{\omega}\hat{\bar{\omega}}_{t+1} + \frac{\Theta_{\sigma^{\omega}}^C\left(\bar{\omega},\sigma^{\omega}\right)}{\Theta^C\left(\bar{\omega},\sigma^{\omega}\right)}\sigma^{\omega}\hat{\sigma}_t^{\omega} \\
V\hat{V}_t &= \frac{R^k}{\Pi}qk\left[\left(1-\Theta^D\right)\left(\hat{R}_t^k - \hat{\Pi}_t + \hat{q}_{t-1} + \hat{k}_{t-1}\right) - \left(\Theta_{\bar{\omega}}^D\bar{\omega}\hat{\bar{\omega}}_t + \Theta_{\sigma^{\omega}}^D\sigma^{\omega}\hat{\sigma}_{t-1}^{\omega}\right)\right] \\
&- \frac{R^e}{\Pi}d^e\left(\hat{R}_{t-1}^e - \hat{\Pi}_t + \hat{d}_{t-1}^e\right) \\
y^d\hat{y}_t^d &= c^d\hat{c}_t^d + i^d\hat{i}_t^d + g\hat{g}_t + x\hat{x}_t + k\Phi_1\hat{u}_t \\
&- \frac{R^k}{\Pi}qk\left[\Theta^D\left(\hat{R}_t^k - \hat{\Pi}_t + \hat{q}_{t-1} + \hat{k}_{t-1}\right) + \left(\Theta_{\bar{\omega}}^D\bar{\omega}\hat{\bar{\omega}}_t + \Theta_{\sigma^{\omega}}^D\sigma^{\omega}\hat{\sigma}_{t-1}^{\omega}\right)\right]
\end{aligned}
$$

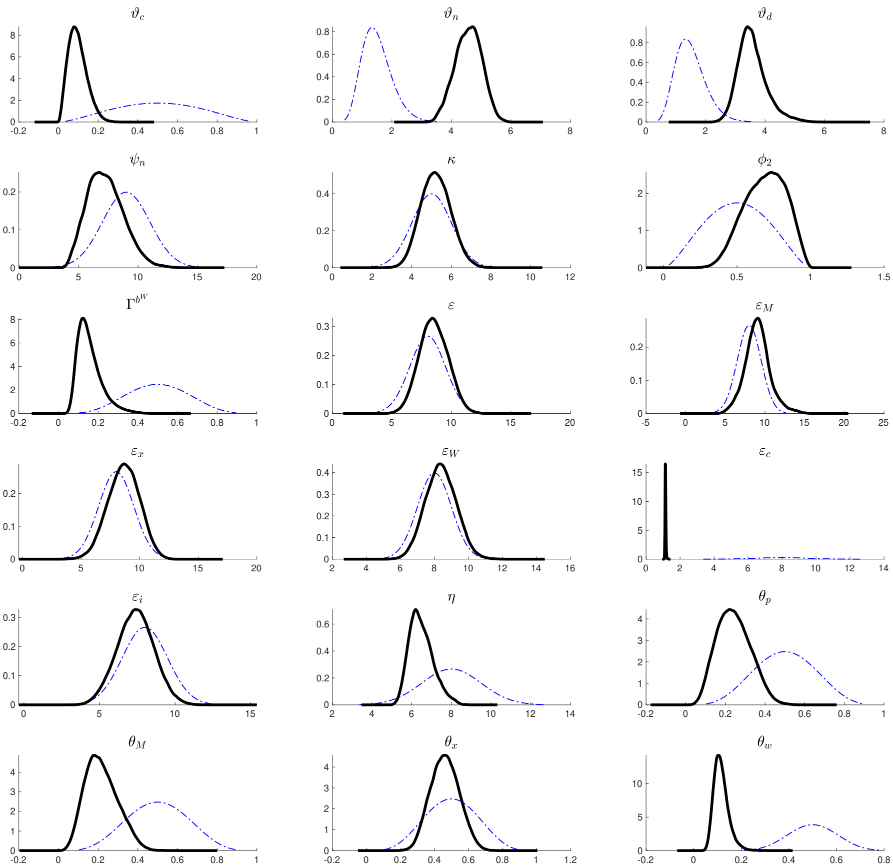
- Derivatives

$$
\begin{aligned}
\Theta_{\bar{\omega}}^A\left(\bar{\omega},\sigma^{\omega}\right) &= 1 - F\left(\bar{\omega},\sigma^{\omega}\right) - \mu_e\bar{\omega}f\left(\bar{\omega},\sigma^{\omega}\right) \\
\Theta_{\sigma^{\omega}}^A\left(\bar{\omega},\sigma^{\omega}\right) &= \Gamma_{\sigma^{\omega}}\left(\bar{\omega},\sigma^{\omega}\right) - \mu_e G_{\sigma^{\omega}}\left(\bar{\omega},\sigma^{\omega}\right) \\
&= -\bar{\omega}F_{\sigma^{\omega}}\left(\bar{\omega},\sigma^{\omega}\right) + \left(1-\mu_e\right)G_{\sigma^{\omega}}\left(\bar{\omega},\sigma^{\omega}\right) \\
\Theta_{\bar{\omega}}^B\left(\bar{\omega},\sigma^{\omega}\right) &= -\Gamma_{\bar{\omega}}\left(\bar{\omega},\sigma^{\omega}\right) \\
&= F\left(\bar{\omega},\sigma^{\omega}\right) - 1 \\
\Theta_{\sigma^{\omega}}^B\left(\bar{\omega},\sigma^{\omega}\right) &= -\Gamma_{\sigma^{\omega}}\left(\bar{\omega},\sigma^{\omega}\right) \\
&= \bar{\omega}F_{\sigma^{\omega}}\left(\bar{\omega},\sigma^{\omega}\right) - G_{\sigma^{\omega}}\left(\bar{\omega},\sigma^{\omega}\right) \\
\Theta_{\bar{\omega}}^D\left(\bar{\omega},\sigma^{\omega}\right) &= \mu_e G_{\bar{\omega}}\left(\bar{\omega},\sigma^{\omega}\right) \\
\Theta_{\sigma^{\omega}}^D\left(\bar{\omega},\sigma^{\omega}\right) &= \mu_e G_{\sigma^{\omega}}\left(\bar{\omega},\sigma^{\omega}\right) \\
\Theta^C\left(\bar{\omega},\sigma^{\omega}\right) &= \frac{\Gamma_{\bar{\omega}}\left(\bar{\omega},\sigma^{\omega}\right)}{\Gamma_{\bar{\omega}}\left(\bar{\omega},\sigma^{\omega}\right) - \mu_e G_{\bar{\omega}}\left(\bar{\omega},\sigma^{\omega}\right)} \\
&= \frac{1 - F\left(\bar{\omega},\sigma^{\omega}\right)}{1 - F\left(\bar{\omega},\sigma^{\omega}\right) - \mu_e\bar{\omega}f\left(\bar{\omega},\sigma^{\omega}\right)}
\end{aligned}
$$

$$
\begin{aligned}
\Theta^C_{\bar{\omega}}(\bar{\omega},\sigma^{\omega}) = & -\frac{f(\bar{\omega},\sigma^{\omega})}{1-F(\bar{\omega},\sigma^{\omega})-\mu_e\bar{\omega}f(\bar{\omega},\sigma^{\omega})} \\
& -\frac{(1-F(\bar{\omega},\sigma^{\omega}))(-f(\bar{\omega},\sigma^{\omega})-\mu_e f(\bar{\omega},\sigma^{\omega})-\mu_e\bar{\omega}f_{\omega}(\bar{\omega},\sigma^{\omega}))}{(1-F(\bar{\omega},\sigma^{\omega})-\mu_e\bar{\omega}f(\bar{\omega},\sigma^{\omega}))^2} \\
= & -\Theta^C(\bar{\omega},\sigma^{\omega})\frac{f(\bar{\omega},\sigma^{\omega})}{1-F(\bar{\omega},\sigma^{\omega})} \\
& -\Theta^C(\bar{\omega},\sigma^{\omega})\frac{-f(\bar{\omega},\sigma^{\omega})-\mu_e f(\bar{\omega},\sigma^{\omega})-\mu_e\bar{\omega}f_{\omega}(\bar{\omega},\sigma^{\omega})}{1-F(\bar{\omega},\sigma^{\omega})-\mu_e\bar{\omega}f(\bar{\omega},\sigma^{\omega})} \\
\Theta^C_{\sigma^{\omega}}(\bar{\omega},\sigma^{\omega}) = & -\frac{F_{\sigma^{\omega}}(\bar{\omega},\sigma^{\omega})}{1-F(\bar{\omega},\sigma^{\omega})-\mu_e\bar{\omega}f(\bar{\omega},\sigma^{\omega})} \\
& -\frac{(1-F(\bar{\omega},\sigma^{\omega}))(-F_{\sigma^{\omega}}(\bar{\omega},\sigma^{\omega})-\mu_e\bar{\omega}f_{\sigma^{\omega}}(\bar{\omega},\sigma^{\omega}))}{(1-F(\bar{\omega},\sigma^{\omega})-\mu_e\bar{\omega}f(\bar{\omega},\sigma^{\omega}))^2} \\
= & -\Theta^C(\bar{\omega},\sigma^{\omega})\frac{F_{\sigma^{\omega}}(\bar{\omega},\sigma^{\omega})}{1-F(\bar{\omega},\sigma^{\omega})} \\
& -\Theta^C(\bar{\omega},\sigma^{\omega})\frac{-F_{\sigma^{\omega}}(\bar{\omega},\sigma^{\omega})-\mu_e\bar{\omega}f_{\sigma^{\omega}}(\bar{\omega},\sigma^{\omega})}{1-F(\bar{\omega},\sigma^{\omega})-\mu_e\bar{\omega}f(\bar{\omega},\sigma^{\omega})}
\end{aligned}
$$

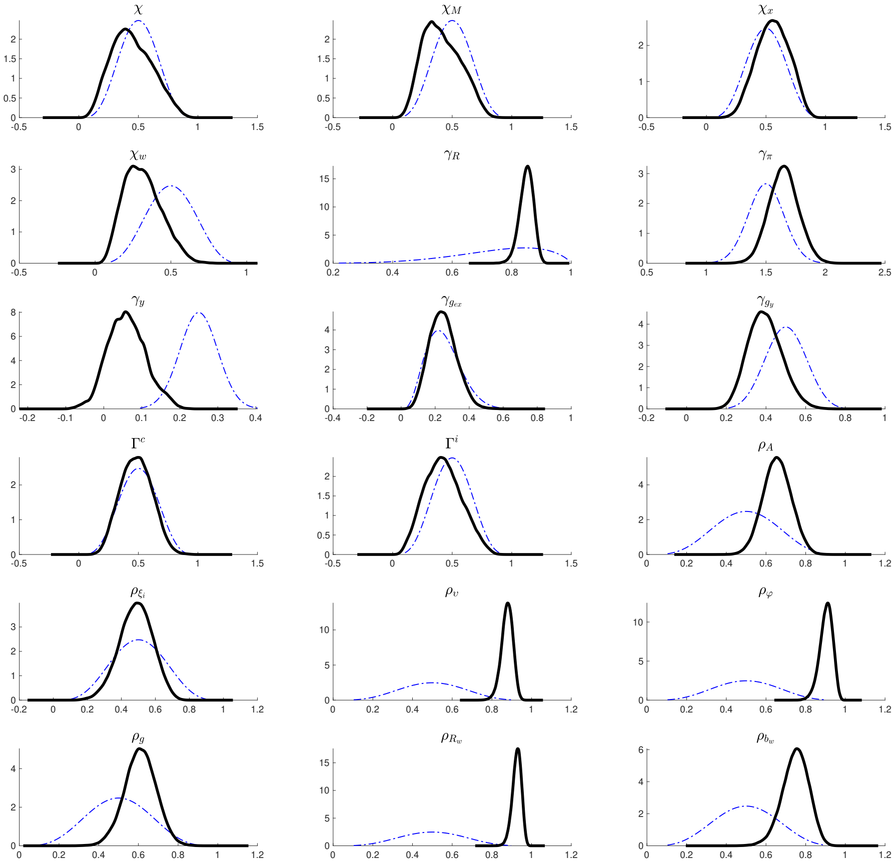
Appendix.3. PRIOR AND POSTERIOR DISTRIBUTIONS

Figure 9: Prior and posterior distributions I



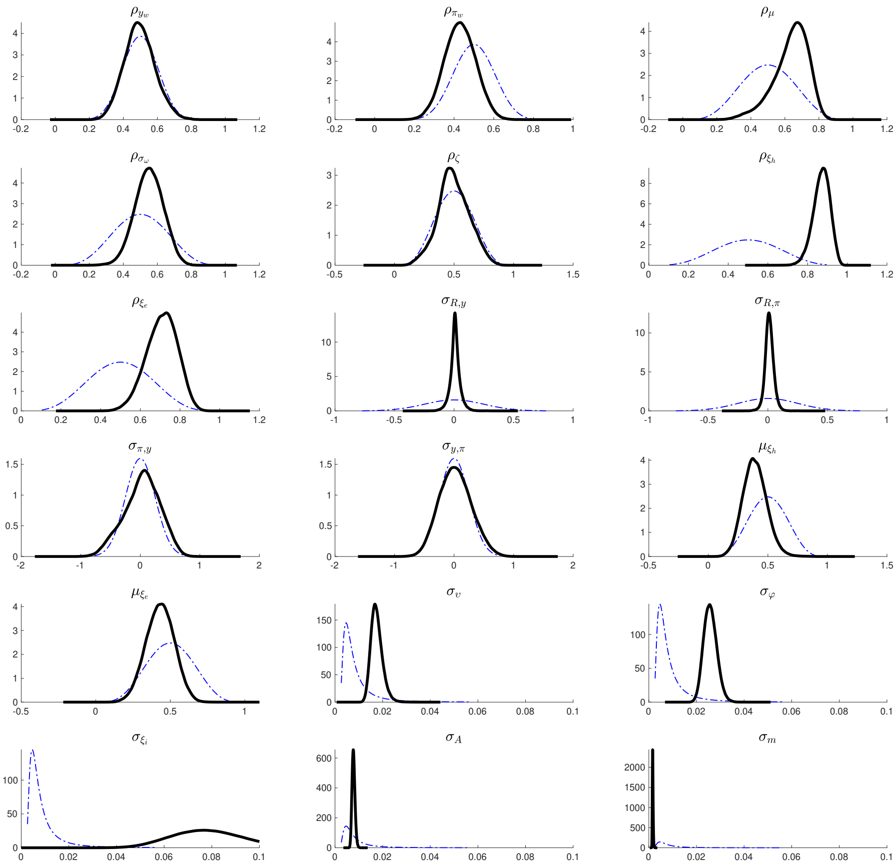
1. Black solid lines are posterior distributions and blue dotted lines are prior distributions.
2. Posterior distributions are based on second half of five million MCMC draws.

Figure 10: Prior and posterior distributions II



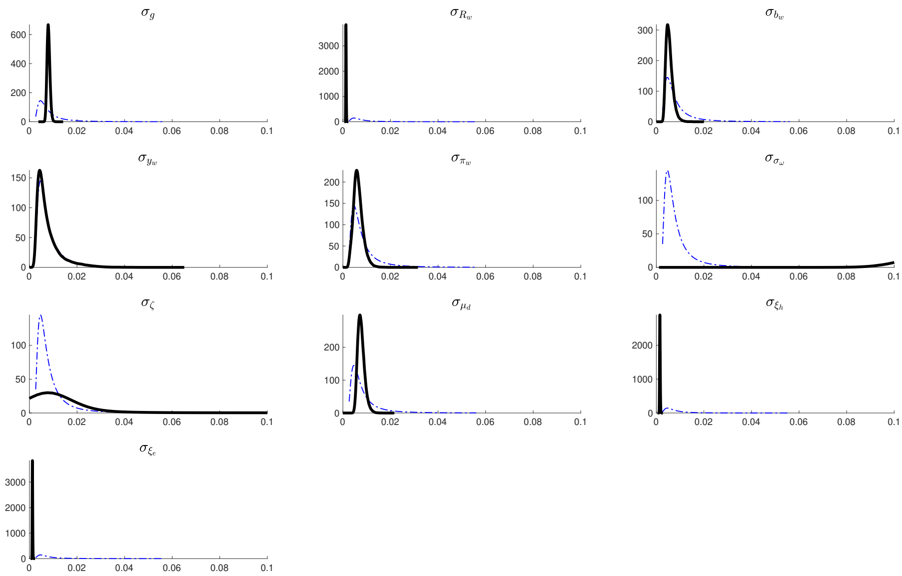
1. Black solid lines are posterior distributions and blue dotted lines are prior distributions.
2. Posterior distributions are based on second half of five million MCMC draws.

Figure 11: Prior and posterior distributions III



1. Black solid lines are posterior distributions and blue dotted lines are prior distributions.
2. Posterior distributions are based on second half of five million MCMC draws.

Figure 12: Prior and posterior distributions IV



1. Black solid lines are posterior distributions and blue dotted lines are prior distributions.
2. Posterior distributions are based on second half of five million MCMC draws.

Appendix.4. ESTIMATION RESULTS OF THE NEW KEYNESIAN MODEL

Table 10: Prior and posterior distributions I of NK model

	Description	Prior Distr.			Posterior Distr.				
		Distr.	Mean	St. Dev.	Mode	Mean	St. Dev.	5%	95%
ϑ_c	Habit persistence	Beta	0.50	0.20	0.2129	0.2128	0.0549	0.1414	0.2816
ϑ_n	Inverse of Frisch labor elasticity	Gamma	1.50	0.50	4.6113	4.5136	0.3180	4.2292	5.0684
ψ_n	Labor supply s.e.	Normal	9.00	2.00	7.6390	7.2560	1.2967	6.1066	9.5153
κ	Investment adjustment cost	Normal	5.00	1.00	5.8435	5.2141	0.7301	5.0425	6.8220
ϕ_2	Capital utilization cost	Beta	0.50	0.20	0.7155	0.6730	0.1306	0.5374	0.8814
Γ^{b^W}	Country risk premium	Beta	0.50	0.15	0.1606	0.1275	0.0632	0.0856	0.2467
ε	Domestic good s.e.	Normal	8.00	1.50	7.3919	7.3045	1.3942	5.6558	9.2308
ε_M	Import good s.e.	Normal	8.00	1.50	8.1765	7.8515	1.2089	6.7126	9.8497
ε_x	Export good s.e.	Normal	8.00	1.50	8.9798	8.6296	1.2287	7.4815	10.7014
ε_W	Foreign good s.e.	Normal	8.00	1.50	-0.6169	-0.6430	0.1957	-0.8887	-0.3777
ε_c	Domestic/foreign consumption s.e.	Normal	8.00	1.50	1.2208	1.1645	0.0760	1.1518	1.3134
ε_i	Domestic/foreign investment s.e.	Normal	8.00	1.50	4.1225	5.4890	1.0961	2.6606	5.5453
η	Labor service s.e.	Normal	8.00	1.50	6.3687	6.5779	0.4201	5.7868	6.8923
θ_p	Domestic price rigidity	Beta	0.50	0.15	0.3347	0.3170	0.1058	0.2224	0.5105
θ_M	Import price rigidity	Beta	0.50	0.15	0.4925	0.5051	0.0349	0.4467	0.5366
θ_x	Export price rigidity	Beta	0.50	0.15	0.5056	0.5156	0.0619	0.4259	0.5865
θ_w	Wage rigidity	Beta	0.50	0.10	0.1267	0.1315	0.0430	0.0677	0.1837
χ	Good price indexation	Beta	0.50	0.15	0.5178	0.3641	0.1817	0.2951	0.7693
χ_M	Import price indexation	Beta	0.50	0.15	0.8018	0.7626	0.0687	0.7123	0.8875
χ_x	Export price indexation	Beta	0.50	0.15	0.5406	0.5646	0.1086	0.3945	0.6769
χ_w	Wage indexation	Beta	0.50	0.15	0.4787	0.3658	0.0891	0.3762	0.6048
γ_R	Taylor rule: interest rate smoothing	Beta	0.75	0.15	0.8549	0.8661	0.0185	0.8304	0.8775
γ_π	Taylor rule: inflation gap	Normal	1.50	0.15	1.6536	1.7300	0.1073	1.5253	1.8050
γ_y	Taylor rule: output gap	Normal	0.25	0.05	0.1240	0.0770	0.0383	0.0740	0.1734
$\gamma_{g_{ex}}$	Taylor rule: exchange rate gap	Beta	0.25	0.10	0.0181	0.0163	0.0064	0.0105	0.0268
γ_{g_y}	Fiscal rule: automatic stabilizer	Beta	0.50	0.10	0.4059	0.5072	0.0780	0.3045	0.5120
Γ^c	Consumption import cost	Beta	0.50	0.15	0.5589	0.4387	0.1047	0.4272	0.7065
Γ^i	Investment import cost	Beta	0.50	0.15	0.7699	0.7963	0.0876	0.6546	0.8864

Note:
1) Posterior distributions are based on second half of five million MCMC draws.
2) Statistics of posterior distributions are rounded to four decimal places.
3) "s.e." stands for substitution elasticity.

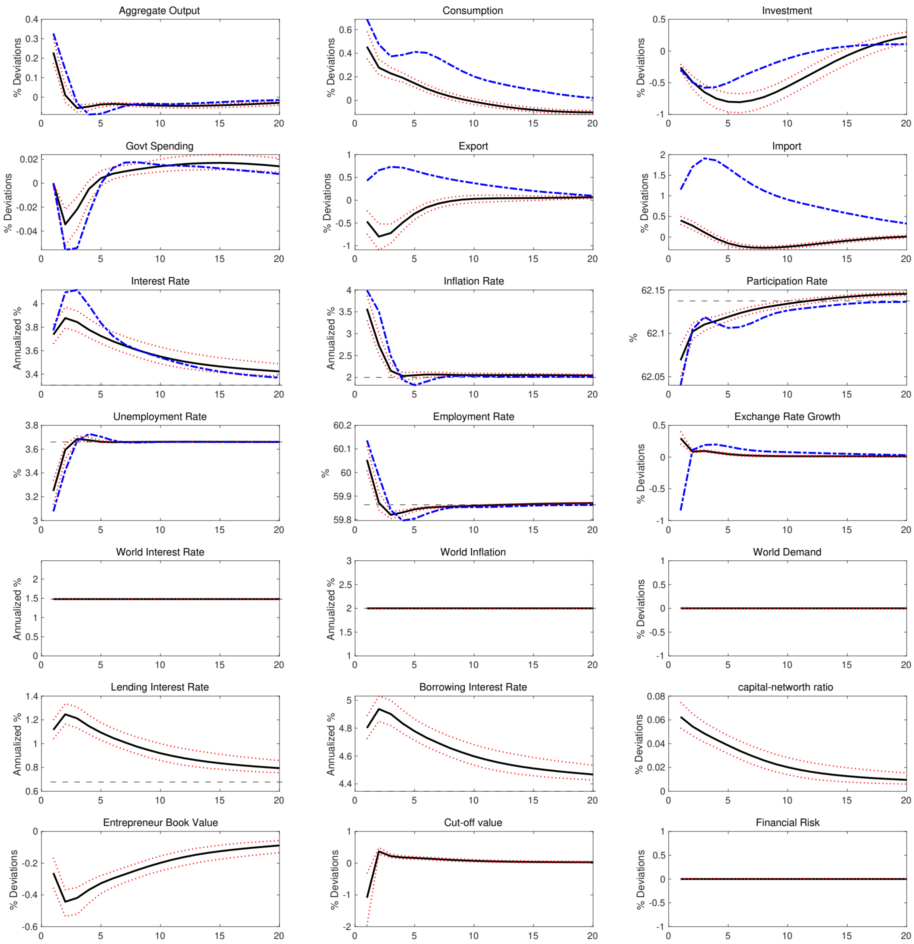
Table 11: Prior and posterior distributions II of NK model

	Description	Prior Distr.			Posterior Distr.				
		Distr.	Mean	St. Dev.	Mode	Mean	St. Dev.	5%	95%
ρ_A	TFP AR(1)	Beta	0.50	0.15	0.5965	0.5288	0.0620	0.5198	0.6759
ρ_{ξ_i}	Investment technology AR(1)	Beta	0.50	0.15	0.4198	0.5191	0.0964	0.2842	0.5397
ρ_υ	Intertemporal preference AR(1)	Beta	0.50	0.15	0.8531	0.8825	0.0260	0.8191	0.8854
ρ_φ	Intratemporal preference AR(1)	Beta	0.50	0.15	0.8698	0.8931	0.0416	0.8155	0.9215
ρ_g	Gov't consumption AR(1)	Beta	0.50	0.15	0.5747	0.5663	0.0827	0.4771	0.6817
ρ_{R_w}	Foreign interest rate AR(1)	Beta	0.50	0.15	0.9322	0.9516	0.0217	0.9030	0.9588
ρ_{b_w}	Country premium AR(1)	Beta	0.50	0.15	0.2824	0.2398	0.0581	0.2068	0.3583
ρ_{y_w}	Foreign demand AR(1)	Beta	0.50	0.10	0.5468	0.5837	0.0603	0.4720	0.6287
ρ_{π_w}	Foreign inflation AR(1)	Beta	0.50	0.10	0.8836	0.8917	0.0280	0.8460	0.9182
ρ_{μ_d}	Price markup AR(1)	Beta	0.50	0.15	0.6361	0.6819	0.1070	0.4989	0.7908
$\sigma_{R,y}$	Correlation R^w, y^w	Normal	0.00	0.25	0.0091	0.0050	0.0055	0.0021	0.0161
$\sigma_{R,\pi}$	Correlation R^w, Π^w	Normal	0.00	0.25	0.0059	0.0169	0.0060	-0.0012	0.0141
$\sigma_{\pi,y}$	Correlation Π^w, y^w	Normal	0.00	0.25	-0.1820	-0.1720	0.1685	-0.3878	0.0310
$\sigma_{y,\pi}$	Correlation y^w, Π^w	Normal	0.00	0.25	0.0882	0.1664	0.1508	-0.0997	0.2858
σ_d	Intertemporal preference shock s.d.	InvGamma	0.01	0.10	0.0202	0.0207	0.0023	0.0173	0.0232
σ_φ	Intratemporal preference shock s.d.	InvGamma	0.01	0.10	0.0284	0.0281	0.0026	0.0252	0.0319
σ_μ	Investment technology shock s.d.	InvGamma	0.01	0.10	0.0986	0.0786	0.0174	0.0783	0.1223
σ_A	TFP shock s.d.	InvGamma	0.01	0.10	0.0078	0.0080	0.0006	0.0071	0.0086
σ_m	Monetary policy shock s.d.	InvGamma	0.01	0.10	0.0015	0.0014	0.0001	0.0013	0.0017
σ_g	Government consumption shock s.d.	InvGamma	0.01	0.10	0.0080	0.0085	0.0006	0.0072	0.0088
σ_{R^W}	Foreign interest rate shock s.d.	InvGamma	0.01	0.10	0.0013	0.0012	0.0001	0.0012	0.0014
$\sigma_{\xi_b W}$	Country risk premium shock s.d.	InvGamma	0.01	0.10	0.0866	0.0874	0.0199	0.0624	0.1131
σ_{y^W}	Foreign demand shock s.d.	InvGamma	0.01	0.10	0.0263	0.0253	0.0022	0.0235	0.0292
σ_{π^W}	Foreign inflation rate shock s.d.	InvGamma	0.01	0.10	0.0271	0.0225	0.0069	0.0192	0.0366
σ_{μ^d}	Price markup shock s.d.	InvGamma	0.01	0.10	0.0106	0.0087	0.0032	0.0077	0.0155

Note: 1) Posterior distributions are based on second half of five million MCMC draws.
2) Statistics of posterior distributions are rounded to four decimal places.
3) "s.d." stands for standard deviation.

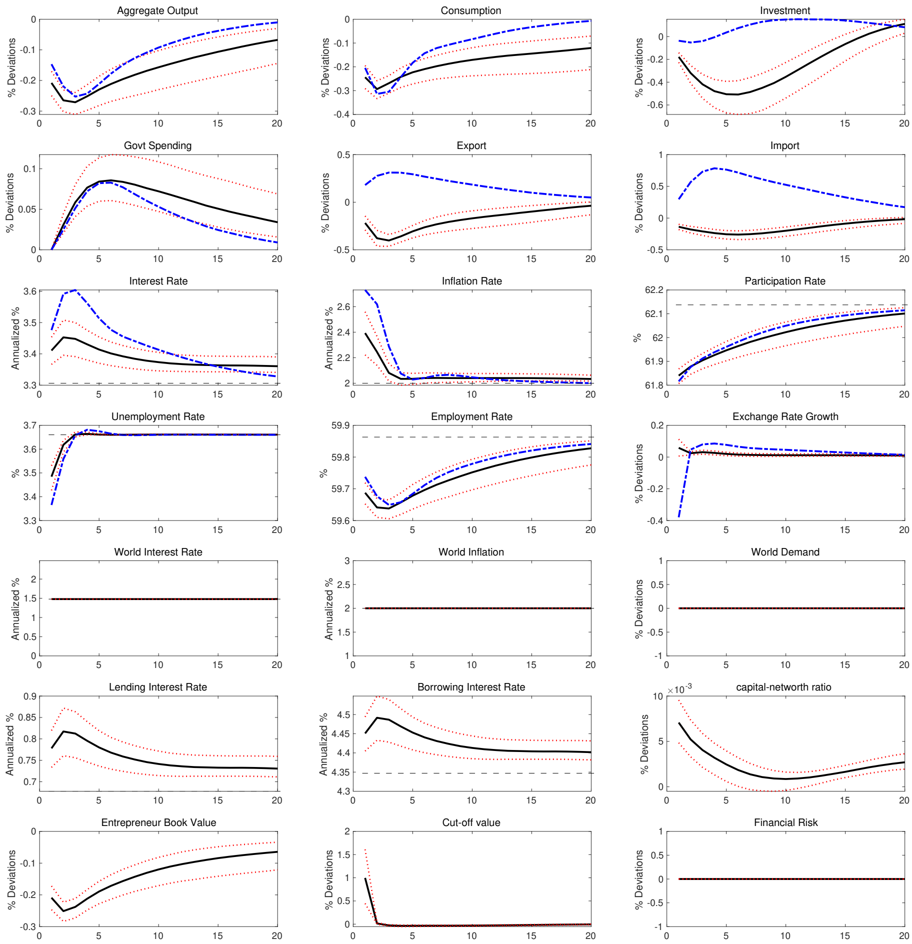
Appendix.5. IMPULSE RESPONSE FUNCTIONS

Figure 13: IRFs to intertemporal preference shock, ε_t^{υ}



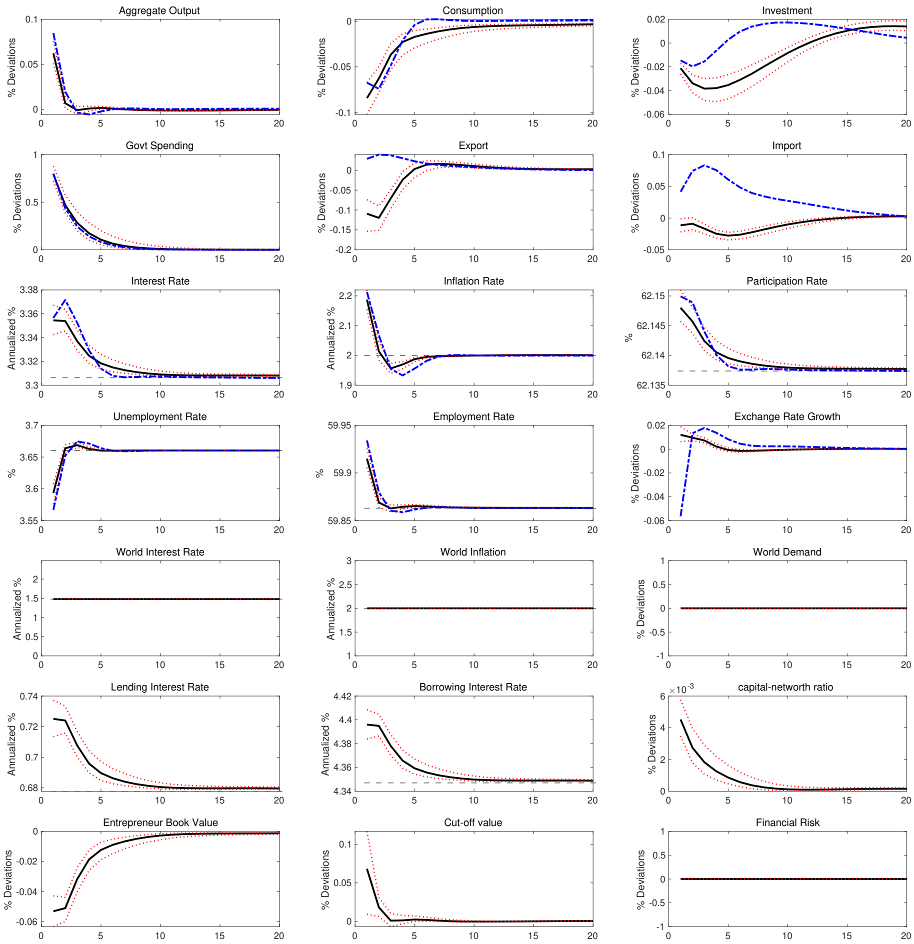
1. Black solid lines are posterior median IRFs.
   Red dotted lines are Bayesian credible intervals with lower bound, 10%, and upper bound, 90%.
   Black dashed lines are the steady state levels of selected variables: interest rates, inflation rates, and labor market indicators.
   Blue dash-dotted lines are IRFs of the New Keynesian model.
2. Units on y-axis may differ across variables: % is percentage in levels, % deviation is log-deviation from steady states and Annualized % is percentage per annum.

Figure 14: IRFs to intratemporal preference shock, ε_t^{φ}



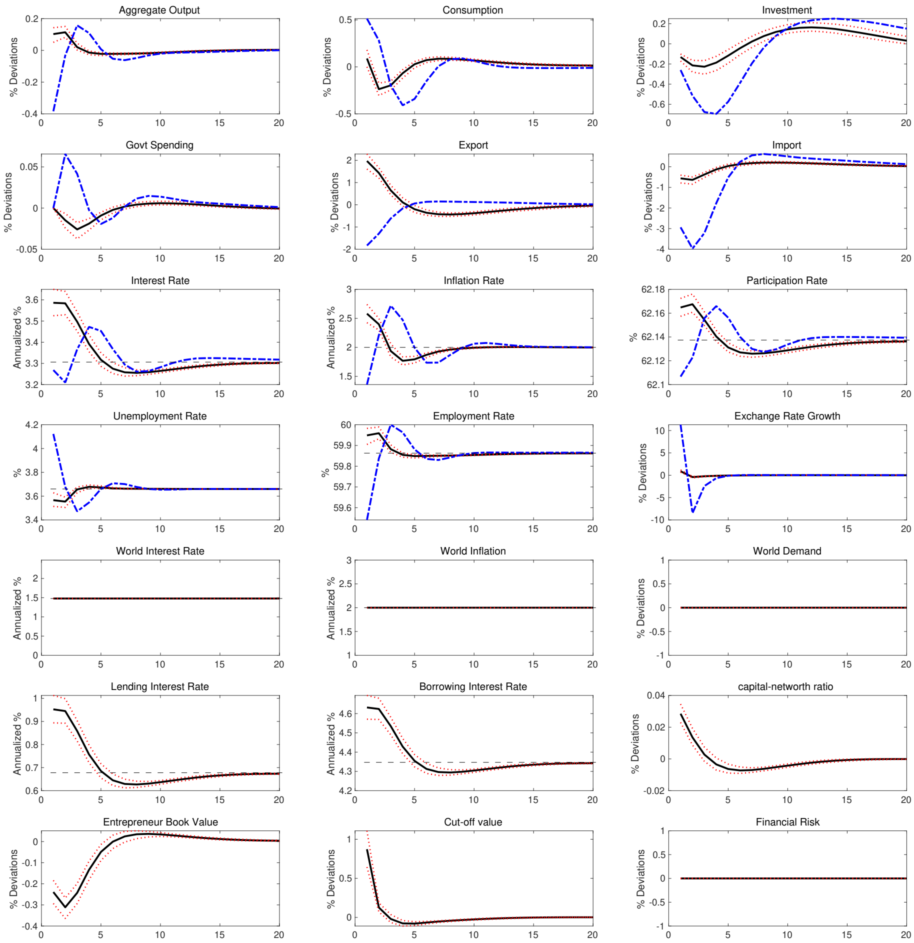
1. Black solid lines are posterior median IRFs.
   Red dotted lines are Bayesian credible intervals with lower bound, 10%, and upper bound, 90%.
   Black dashed lines are the steady state levels of selected variables; interest rates, inflation rates, and labor market indicators.
   Blue dash-dotted lines are IRFs of the New Keynesian model.
2. Units on y-axis may differ across variables: % is percentage in levels, % deviation is log-deviation from steady states and Annualized % is percentage per annum.

Figure 15: IRFs to government spending shock, ε_t^g



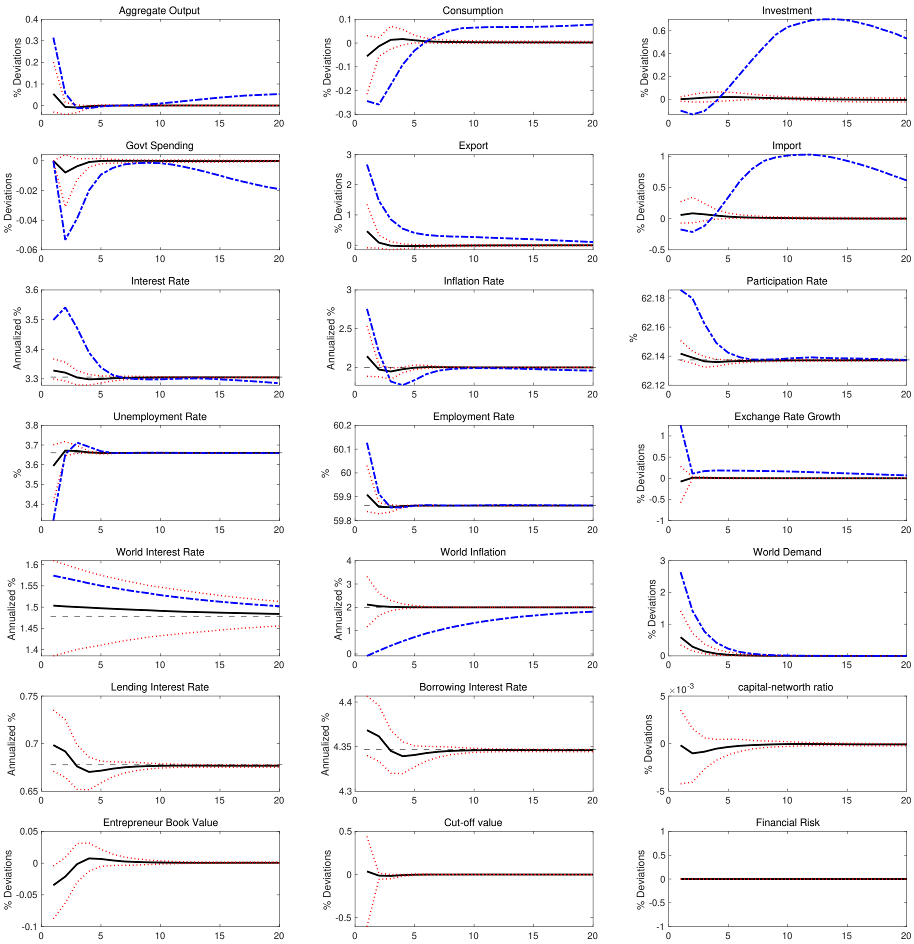
1. Black solid lines are posterior median IRFs.
   Red dotted lines are Bayesian credible intervals with lower bound, 10%, and upper bound, 90%.
   Black dashed lines are the steady state levels of selected variables; interest rates, inflation rates, and labor market indicators.
   Blue dash-dotted lines are IRFs of the New Keynesian model.
2. Units on y-axis may differ across variables: % is percentage in levels, % deviation is log-deviation from steady states and Annualized % is percentage per annum.

Figure 16: IRFs to country premium shock, $\varepsilon_t^{b_w}$



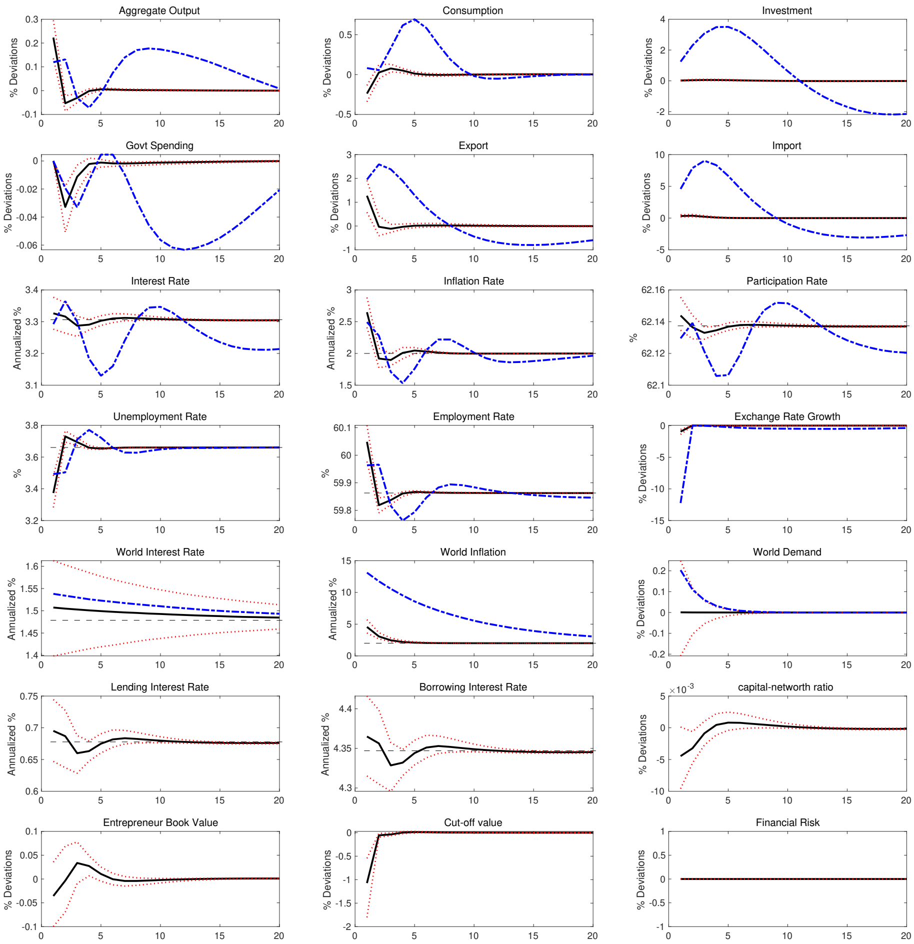
1. Black solid lines are posterior median IRFs.
   Red dotted lines are Bayesian credible intervals with lower bound, 10%, and upper bound, 90%.
   Black dashed lines are the steady state levels of selected variables; interest rates, inflation rates, and labor market indicators.
   Blue dash-dotted lines are IRFs of the New Keynesian model.
2. Units on y-axis may differ across variables: % is percentage in levels, % deviation is log-deviation from steady states and Annualized % is percentage per annum.

Figure 17: IRFs to foreign demand shock, ε^{y_w}



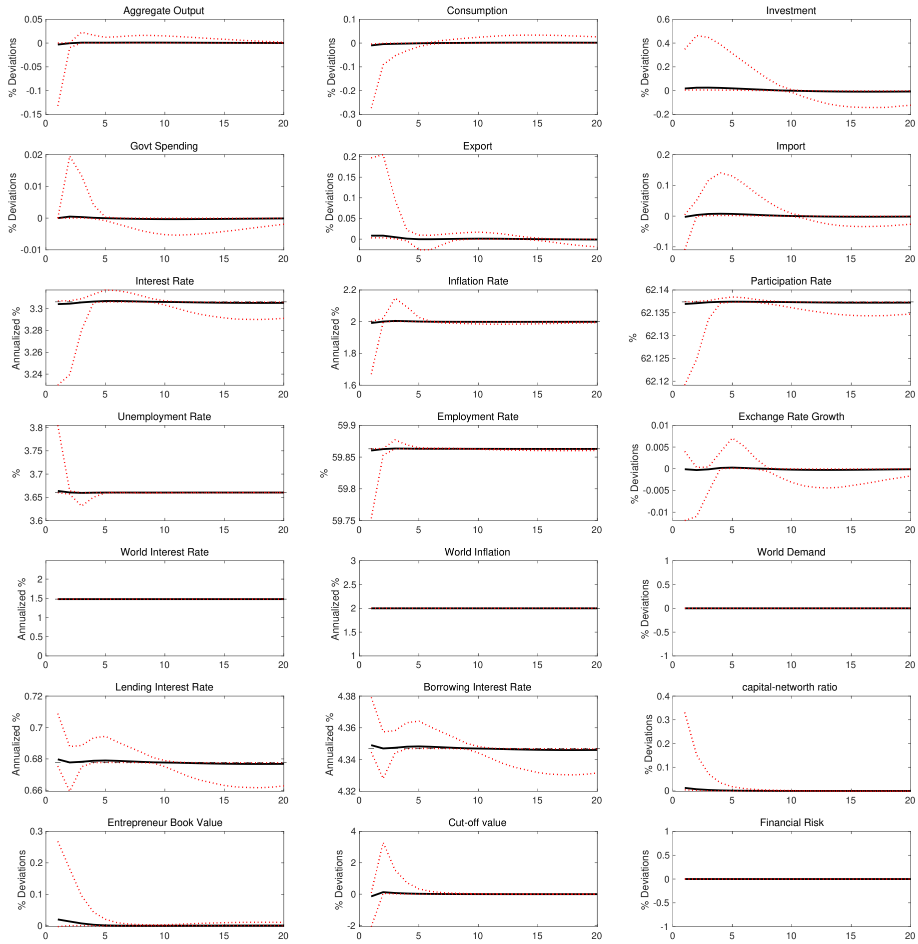
1. Black solid lines are posterior median IRFs.
   Red dotted lines are Bayesian credible intervals with lower bound, 10%, and upper bound, 90%.
   Black dashed lines are the steady state levels of selected variables; interest rates, inflation rates, and labor market indicators.
   Blue dash-dotted lines are IRFs of the New Keynesian model.
2. Units on y-axis may differ across variables: % is percentage in levels, % deviation is log-deviation from steady states and Annualized % is percentage per annum.

Figure 18: IRFs to foreign inflation shock, ε^{π_w}



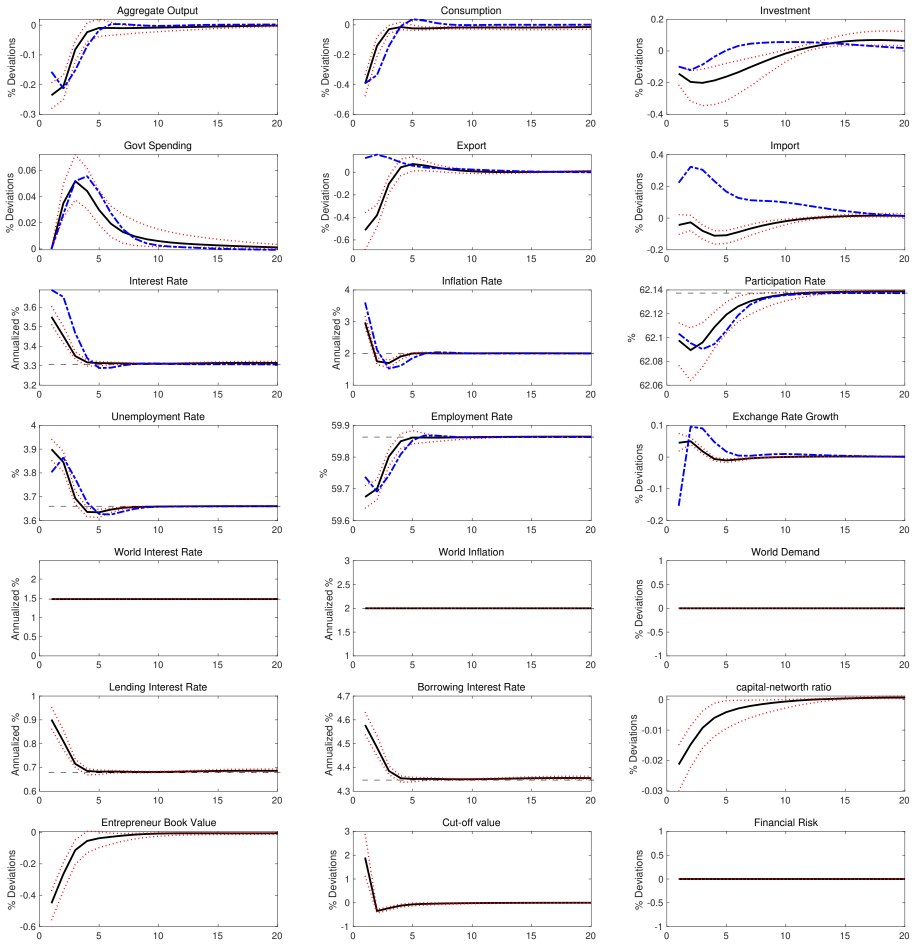
1. Black solid lines are posterior median IRFs.
   Red dotted lines are Bayesian credible intervals with lower bound, 10%, and upper bound, 90%.
   Black dashed lines are the steady state levels of selected variables; interest rates, inflation rates, and labor market indicators.
   Blue dash-dotted lines are IRFs of the New Keynesian model.
2. Units on y-axis may differ across variables: % is percentage in levels, % deviation is log-deviation from steady states and Annualized % is percentage per annum.

Figure 19: IRFs to financial wealth shock, ε^{ζ}



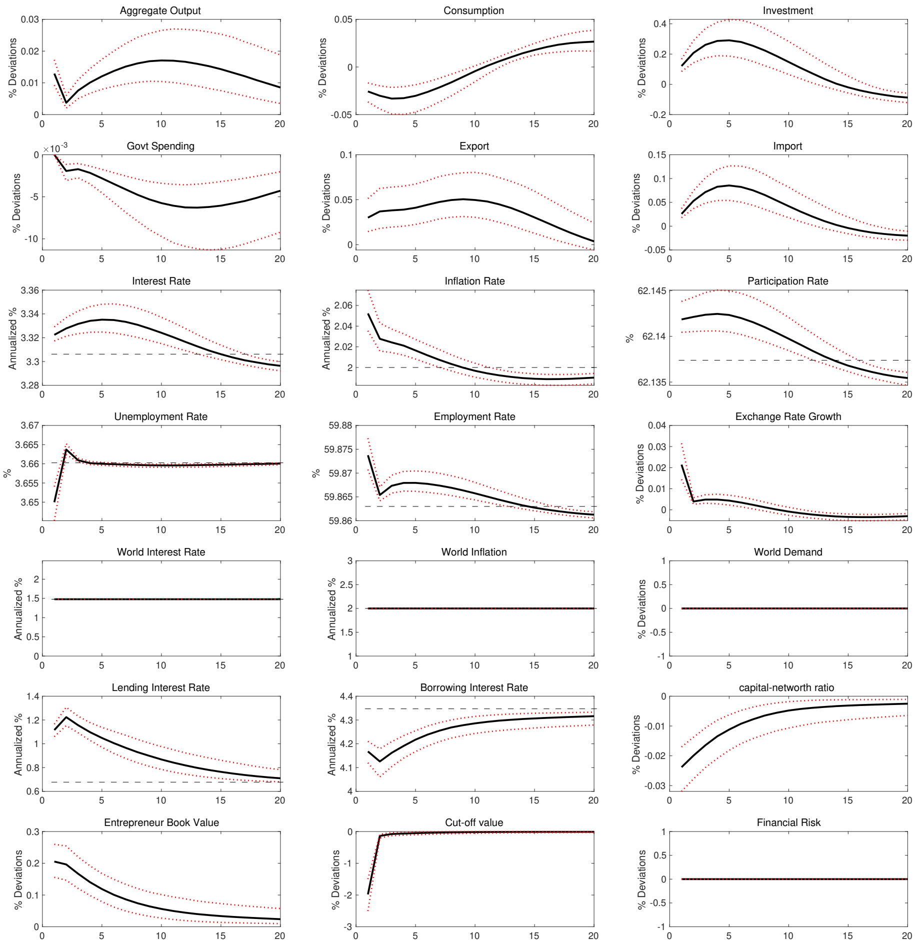
1. Black solid lines are posterior median IRFs.
   Red dotted lines are Bayesian credible intervals with lower bound, 10%, and upper bound, 90%.
   Black dashed lines are the steady state levels of selected variables: interest rates, inflation rates, and labor market indicators.
2. Units on y-axis may differ across variables: % is percentage in levels, % deviation is log-deviation from steady states and Annualized % is percentage per annum.

Figure 20: IRFs to price markup shock, $\varepsilon_t^{\mu_d}$



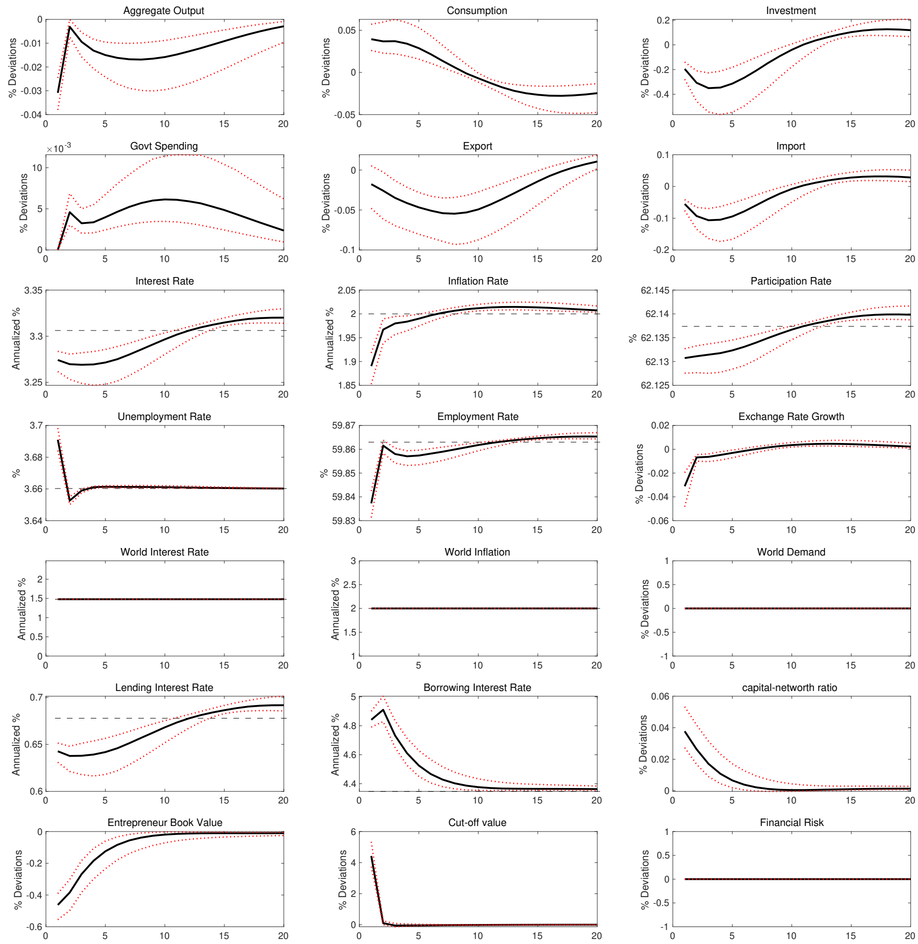
1. Black solid lines are posterior median IRFs.
   Red dotted lines are Bayesian credible intervals with lower bound, 10%, and upper bound, 90%.
   Black dashed lines are the steady state levels of selected variables: interest rates, inflation rates, and labor market indicators.
   Blue dash-dotted lines are IRFs of the New Keynesian model.
2. Units on y-axis may differ across variables: % is percentage in levels, % deviation is log-deviation from steady states and Annualized % is percentage per annum.

Figure 21: IRFs to deposit interest rate shock, $\varepsilon_t^{\xi_h}$



1. Black solid lines are posterior median IRFs.
   Red dotted lines are Bayesian credible intervals with lower bound, 10%, and upper bound, 90%.
   Black dashed lines are the steady state levels of selected variables; interest rates, inflation rates, and labor market indicators.
2. Units on y-axis may differ across variables: % is percentage in levels, % deviation is log-deviation from steady states and Annualized % is percentage per annum.

Figure 22: IRFs to loan interest rate shock, $\varepsilon_t^{\xi_e}$



1. Black solid lines are posterior median IRFs.
   Red dotted lines are Bayesian credible intervals with lower bound, 10%, and upper bound, 90%.
   Black dashed lines are the steady state levels of selected variables; interest rates, inflation rates, and labor market indicators.
2. Units on y-axis may differ across variables: % is percentage in levels, % deviation is log-deviation from steady states and Annualized % is percentage per annum.

Appendix.6. HISTORICAL SHOCK DECOMPOSITIONS OF VARIABLES

Figure 23: Smoothed historical shocks

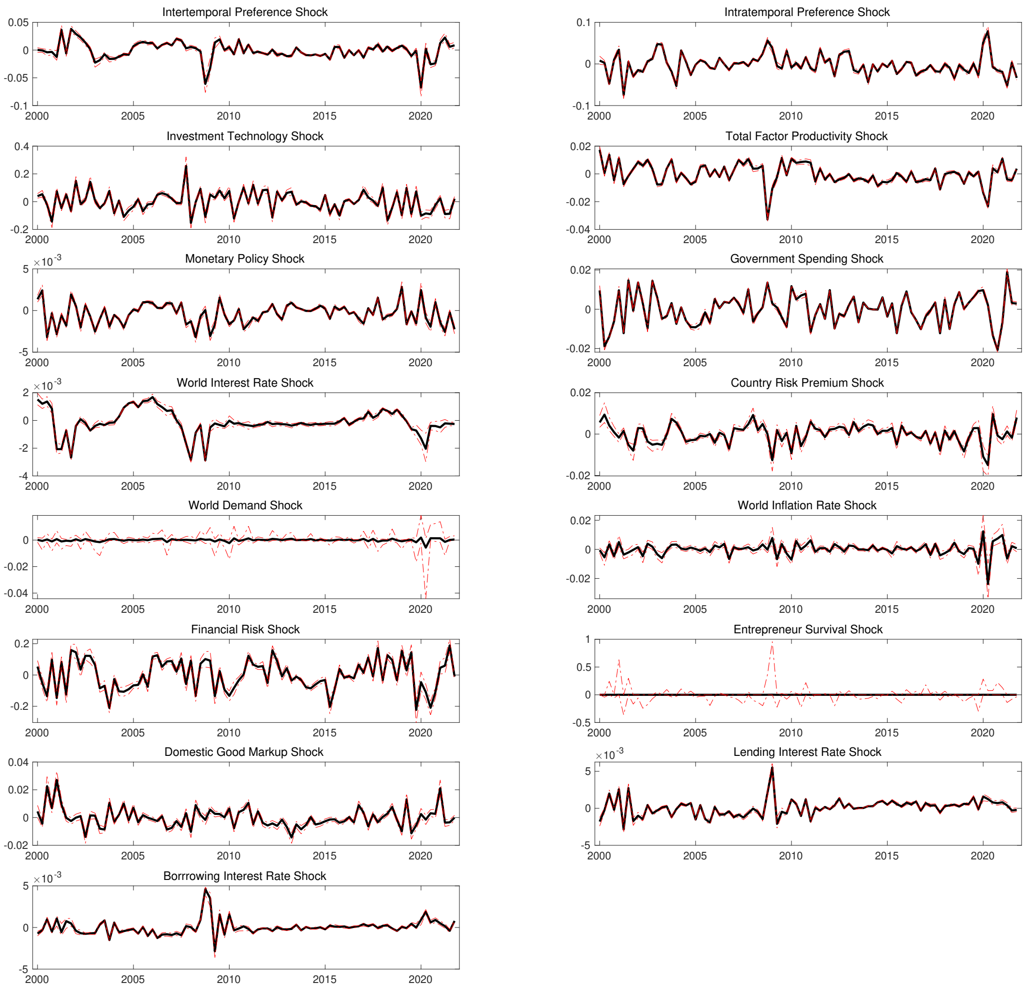


Figure 24: Historical shock decomposition of inflation rate (Demeaned)

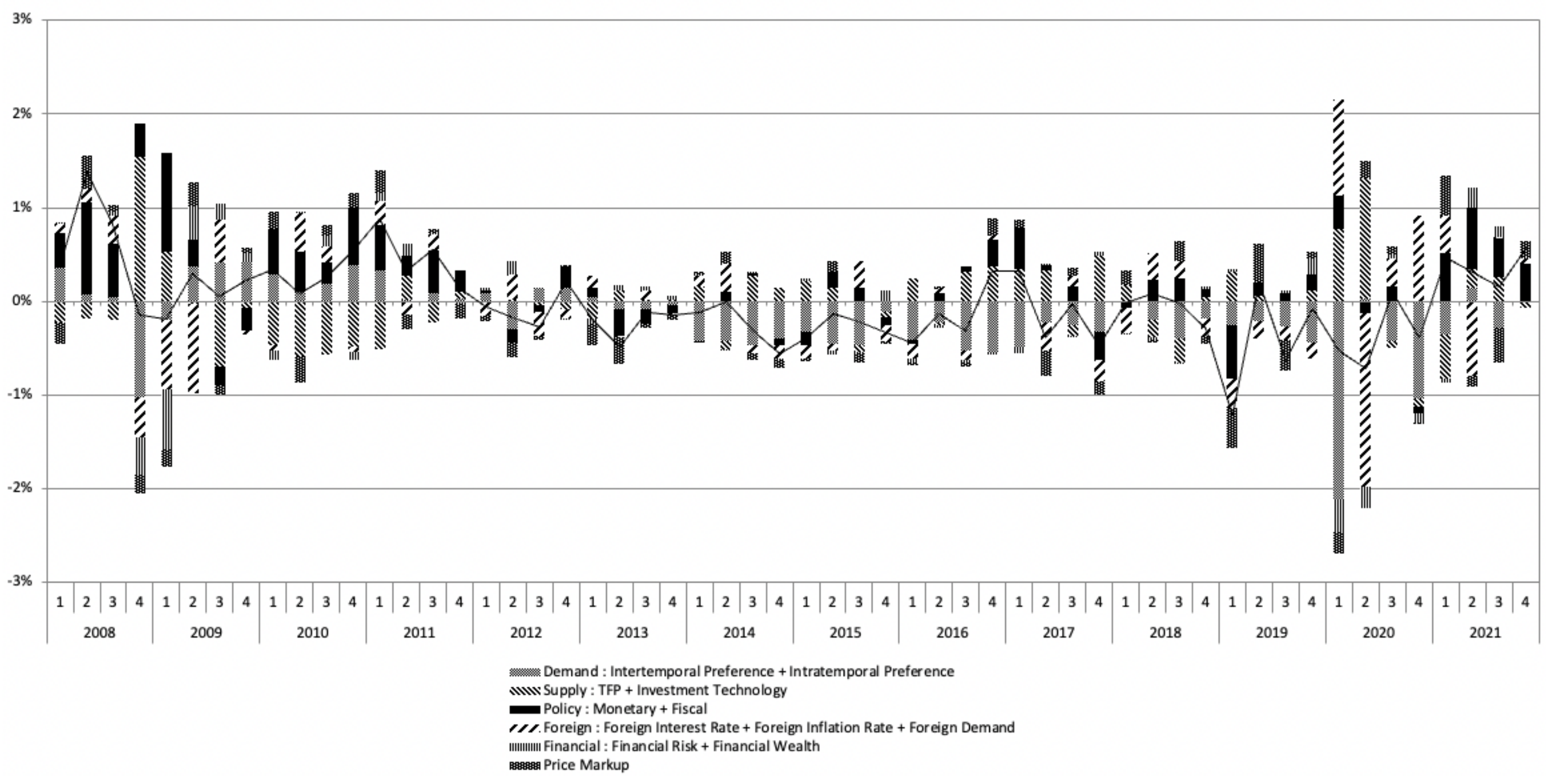


Figure 25: Historical shock decomposition of employment rate (Demeaned)

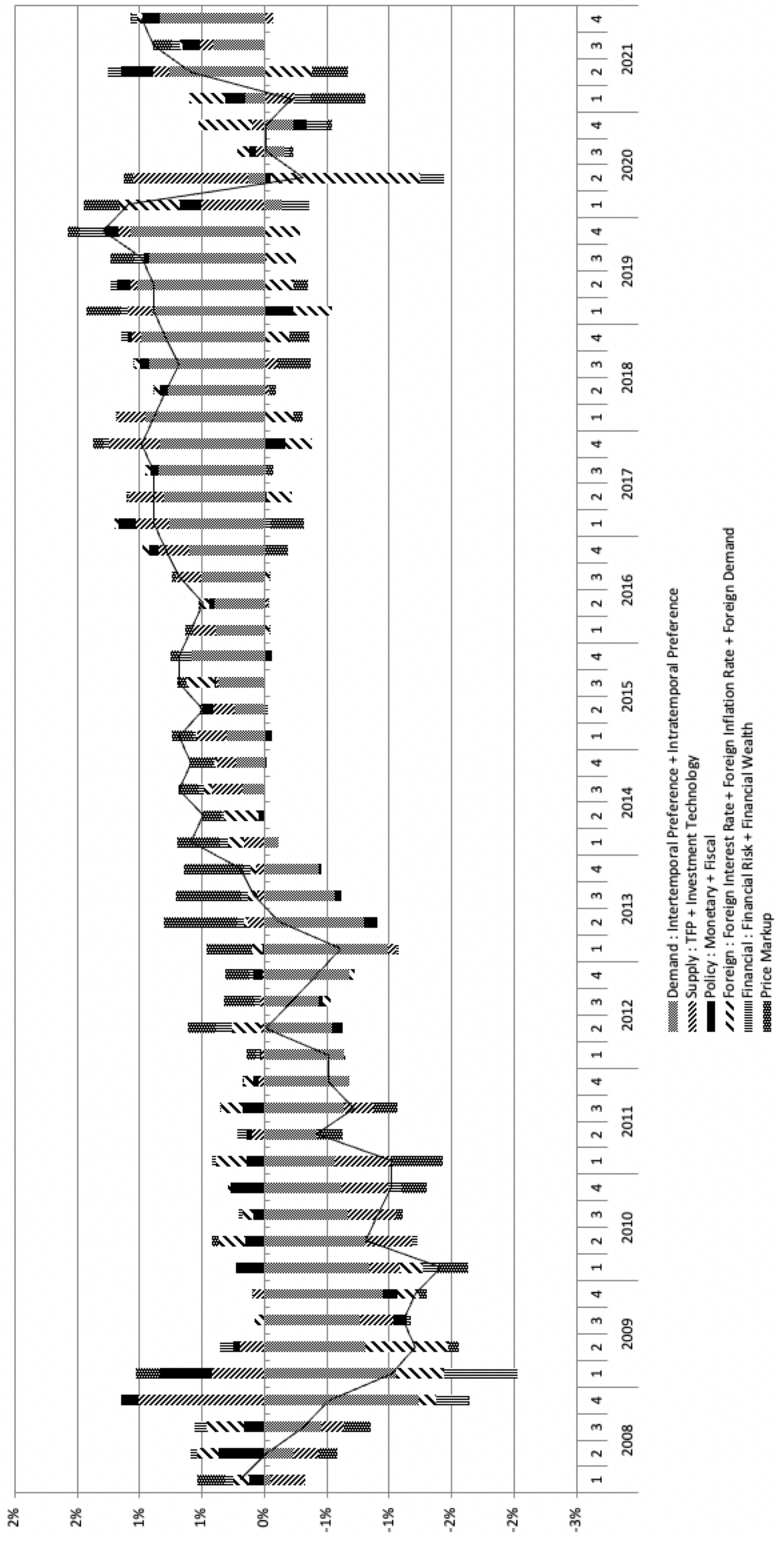


Figure 26: Historical shock decomposition of consumption (HP Detrended)