Financial cycle and conduct of monetary policy: The amplifier/divider theory

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Abstract: The financial cycle can play a decisive role in the transmission of monetary policy decisions. The impact of these decisions is amplified when the financial cycle is positive, and it is compressed when this cycle is negative. Considering this amplifier/divider mechanism in a semi-structural NKM, estimated for the US economy using Bayesian techniques, confirms this conclusion and improves the decision of raising or lowering the interest rate. The information on the financial cycle also allows a better identification of the inflationary and disinflationary pressures due to the impact of this cycle on the balance between supply and demand of the economy through its action on financing conditions.

Key words: Financial cycle, monetary policy, New Keynesian Model, output gap, Bayesian estimation.

JEL classification: C11, C32, E30, E50.

I. Introduction

The important relationship between the financial cycle and the real cycle is proven both theoretically and empirically. Economists give greater importance to the role of financial dynamics on real activity. The review of the practices of national and international economic and financial institutions reveals that they are also convinced by this importance. Since 2008, their decision-making frameworks start to incorporate models with some financial variables such as credit and real estate prices. These models use, particularly, financial accelerator mechanisms to amplify real shocks.

This work sheds light on another mechanism by which financial dynamics can affect real activity, through its impact on the transmission of monetary policy decisions. In fact, the perception of risk and the psychology of agents play a very important role in their reactions to monetary policy decisions. The position of the financial cycle represents a very good aggregate indicator of these aspects: When economic agents are optimistic, they are less risk-averse, financing constraints are weak, the financial cycle is positive, and consumption and investment decisions are made more easily. But when the economic agents are pessimistic, they are more risk-averse, the financing constraints are important, the financial cycle is negative, and the decisions of these agents are more motivated by precaution. In the face of a negative demand shock, monetary policy will therefore need less effort to revive activity when the financial cycle is positive. In contrast, when pessimism takes place, the effort needed to revive will necessarily be greater. More specifically, a positive financial cycle acts as an amplifier for monetary policy decisions that are then more easily transmitted. In contrast, a negative financial cycle plays the role of a divider for monetary policy decisions which are transmitted more difficultly in this case.

Based on a semi-structural NKM, this work proposes an integrated framework to endogenously capture this amplifier/divider mechanism that the financial cycle plays. The cyclical and trend components of the financial dynamics are also estimated in an endogenous way. In addition to an IS curve, a Phillips curve, an Okun's law and a monetary policy rule, the proposed specification contains an additional block describing the dynamics of the financial sphere and its interaction with the real sphere. The IS curve is also augmented to further track this interaction and capture the amplifier/divider effect of the financial cycle on the transmission of monetary policy. The fact of resting on the theoretical foundations of the new synthesis makes a set of criticisms formulated vis-à-vis the NKM valid for this contribution also. However, this work has several advantages that distinguish it from the others. First, it allows a quantification of the impact of the financial cycle on the transmission of monetary policy. Second, it proposes an explicit estimate of the financial cycle derived from a framework that incorporates a set of theoretical and empirical consensus. Third, it allows an evaluation of the transmission of financial shocks to real activity and vice-versa. Fourth, it allows for an output gap estimation that considers the impact of financial dynamics on the balance between the supply and the demand of the economy. Last, the model parameters are estimated on real data using Bayesian techniques.

The rest of the document is presented as follows. The second section highlights the importance and challenges of integrating finance into macroeconomic analysis, after a return to the related academic debate and empirical practice. The third section presents the details of the theoretical specification adopted in this work. Model parameters are estimated for the US economy using Bayesian techniques. The last section discusses the results and their implications for the conduct of monetary policy.

II. The reconciliation of macroeconomics and finance

One of the weaknesses in the development of macroeconomic theory remains its ignorance of finance when it comes to explaining real fluctuations. In the same way that Keynesians and Monetarists ignored Fisher's work (1933), the new synthesis surprisingly ignored all the literature of the 1980s and 1990s that demonstrated the significant economic effect of financial factors on real activity. Woodford (2003) and his ignorance of some contributions like Kiyotaki and Moore (1997) or Bernanke *et al.* (1999) typically illustrates this finding.

Indeed, financial factors have gradually disappeared from macroeconomists' radars, and finance became a factor that could be ignored when trying to understand real fluctuations. This would have been justified if the financial markets were perfect and complete. In this case, the channels through which the financial shocks would affect the real economy would be interest rates and exchange rates (price channels). But this is not what is happening in the real world, and a body of empirical evidence exists to show that. The first work supporting the transmission of financial shocks to real activity through non-price channels dates back at least from the early 1930s in the aftermath of the Great Depression. Fisher (1933) largely attributed the severity of this depression to the excessive leverage before the crisis and subsequent deflation. The causal chain of events enumerated by Fisher contains many elements that appear today in recent discussions (e.g., fire sales, credit rationing, precautionary saving, ...). Unfortunately, Fisher's work quickly eclipsed in front of the dominant Keynesian and Monetarist paradigms. However, the most surprising remains the negligence of this aspects by the new synthesis. The works showing that monetary factors were insufficient to explain the dynamics of macroeconomic activity was already available before the publication of Woodford's (2003) work.

In the late 1970s and early 1980s, Mishkin (1978) and Bernanke (1983) argued that financial factors, including bank loans, had an independent economic effect in addition to the effect of money supply. In contrast to the Monetarists, these works initially emphasized the fact that the transmission of monetary shocks is also done by the quantities (credit channel), then they claimed that the financial shocks related to assets prices were most important than monetary shocks. Bernanke and Gertler (1989, 1995) then Bernanke *et al.* (1999) showed that the financial system can not only amplify macroeconomic shocks through the financial accelerator mechanism, but it can be a source of them. From 2000, there has been a resurgence of works that support these finding. Several economists have pointed out the significant economic effect of cyclical movements (peaks and troughs) of financial variables[1]. The global financial crisis of 2008 has prompted national and international institutions to recognize the existence of a common cycle of financial variables, called the financial cycle, which includes both quantities and prices and which has a significant impact on real activity (BIS (2016)).

For example, admirable efforts have been made by the ECB economists to integrate the impact of financial dynamics on real activity in the institution's analytical framework. However, their most recent model, ECB-Global by Dieppe *et al.* (2017), is unable to provide information on the financial cycle position and to take it into account in the policy response. As this work shows, the amplitude and the nature of this response depends on the financial cycle positioning. Indeed, the psychology of the

[1]Borio *et al*. (2001), Borio et Lowe (2002), Reinhart et Rogoff (2009a, 2009b), Claessens, Kose et Terrones (2011), Borio (2014) et Aikman, Haldane et Nelson (2015).

agents plays a very important role in the amplification of the shocks. In the presence of optimistic expectations, economic policy needs less effort to revive activity. In contrast, when pessimism takes place, the effort needed to revive will necessarily be greater. As pointed out by Borio (2014), the perception of risks by market agents, the attitude of these agents towards these risks and the financing constraints are among the most important factors that impact economic decisions. The fact of having financial accelerator mechanisms that systematically amplify any slowing down of real activity regardless of the agents' expectations may lead to inappropriate policy-decisions.

Moreover, the financial imbalances and the crises that result from them are often the result of significant incoherence between the dynamics of the real sphere and that of the financial sphere. If these two spheres progress in a coherent way, there would probably be no financial imbalances or crises. More concretely, an improvement in the volume of loans or real estate prices due to an improvement in the productivity of the economy would not be a problem. But a productivity shock amplified by too accommodating monetary conditions will encourage over-indebtedness of agents and bubble formation. Similarly, the discouragement of this shock by restrictive monetary conditions will significantly reduce the macroeconomic outlook and the welfare of the agents. Indeed, an improvement in productivity can lead to lower inflation and, as a result, an increase in the real interest rate that will discourage demand through debt. In the presence of positive pressures on the financial cycle, if monetary policy does not consider the amplifier mechanism, then its reaction to the fall in inflation will be over-measured and will lead to too accommodating monetary conditions. Conversely, in the presence of negative pressures on the financial cycle, if monetary policy does not consider the divider mechanism, then its reaction to the decline in inflation will be weak and lead to restrictive monetary conditions.

Thus, it is difficult to imagine a macroeconomic decision that does not have the concern of the coherence between the dynamics of the real sphere and that of the financial sphere. This coherence begins with an analytical framework that takes it into account. From a practical point of view, the challenge is the specification to describe the dynamics of the financial cycle and its interaction with the real sphere. Especially, this cycle is not only unobservable as for the real cycle, but there is no aggregate indicator that provides information on the financial dynamics as does the GDP for real dynamics. Fortunately, the great interest in variables that can better describe and reflect the financial cycle, their predictive content of financial instability and their relationship to the business cycle has led to a consensus on the credit and the real estate prices. In a kind of synthesis of the research on the question, Borio (2014) points out that the combination between credit growth and real estate prices appears to be the most parsimonious way of describing the financial cycle and its link with the business cycle and financial crises. Analytically, it is the smallest set of variables needed to correctly reproduce the interaction between financing constraints (credit) and perceptions of value and risk (real estate prices). Therefore, as long as it is possible to construct a composite indicator that aggregates the dynamics of the credit and the property prices, then the challenge becomes the decomposition of this indicator into structural and cyclical components while considering the interaction between the real sphere and the financial sphere of the economy.

III. A semi-structural NKM with financial cycle and a new IS curve

This paper suggests leading the decomposition of financial dynamics in a semi-structural NKM framework. In addition to the IS curve, the Phillips curve and the monetary policy rule, the proposed specification adds an additional block describing the dynamics of the financial sphere and its interaction with the real sphere.

First, it is assumed that the financial dynamics of the economy is divided into structural and cyclical components. The dynamics of the real cycle of the economy is supposed to depend on the past dynamics of the financial cycle and the dynamics of the latter is supposed to depend on the current and anticipated dynamics of the first one. Indeed, considering the impact of the financial cycle on the output gap allows a better appreciation of inflationary (or disinflationary) pressures: the financial cycle can have a direct and an independent impact on the balance between the supply and the demand of the economy through its impact on the financing conditions. The improvement (or deterioration) of these constraints when the financial cycle is positive (negative) encourages (discourages) demand through debt. The gap between this demand and the supply of the economy will lead to inflationary pressures (disinflationary).

Second, the explicit identification of the financial cycle facilitates its use to capture the amplifier/divider mechanism that it plays vis-à-vis the monetary policy. This paper suggests that this mechanism acts independently on the output gap but proportionally to the real interest rate. Consequently, an interaction term between this rate and the financial cycle is added to the IS curve with a negative sign. When the financial cycle is positive, an increase (or decrease) in real interest rate is amplified and the resulting decrease (increase) of the output gap too. When the financial cycle is negative, an increase (or decrease) in real interest rate is compressed and the resulting decrease (increase) of the output gap too.

The adopted specification assumes that real GDP (Y) is determined by its long-term potential ($\bar{Y}$) and the output gap (y):

$$Y_t = \bar{Y}_t + y_t \quad (1)$$

The process of potential GDP ($\bar{Y}$) is supposed to contain two equations as following:

$$\begin{cases} \bar{Y}_t = \bar{Y}_{t-1} + G_t + \varepsilon_t^{\bar{Y}} & (2) \\ G_t = \theta G^{ss} + (1-\theta)G_{t-1} + \varepsilon_t^{G} & (3) \end{cases}$$

This representation assumes that the potential output ($\bar{Y}$) evolves according to a growth rate (G) which is a function of its steady-state (G^{ss}) and the adjustment speed (θ). This process involves two types of shocks: a level shock ($\varepsilon^{\bar{Y}}$) and a growth rate shock (ε^{G}). The two shocks will lead to a permanent change in the level of potential output, but in the second case the rise or fall will take place gradually.

The output gap dynamics follows an augmented IS curve, where φ_1 is the inertia, φ_2 the coefficient of the lagged financial cycle (fi_{t-1}), φ_3 the coefficient of the real interest rate (rr_t), φ_3 the coefficient of the amplifier/divider mechanism which is supposed to result from the interaction between the current financial cycle position (fi_t) and the real interest rate. ε^{y} is an aggregate demand shock:

$$y_t = \varphi_1 y_{t-1} + (1-\varphi_1)y_{t+1} + \varphi_2 fi_{t-1} - \varphi_3 rr_t - \varphi_4 * (rr_t * fi_t) + \varepsilon_t^{y} \quad (4)$$

The model contains four other blocks. The first block links inflation (π) to the output gap through a New-Keynesian Phillips curve:

$$\pi_t = \lambda\pi_{t-1} + (1-\lambda)\pi_{t+1} + \beta y_t + \varepsilon_t^{\pi} \quad (5)$$

The second block links the unemployment rate (U_t) to the output gap through a dynamic Okun's law:

$$\begin{cases} U_t = \bar{U}_t - u_t & (6) \\ u_t = \tau_2 u_{t-1} + \tau_1 y_t + \varepsilon_t^u & (7) \\ \bar{U}_t = (\tau_4 \bar{U}^{ss} + (1-\tau_4)\bar{U}_{t-1}) + g\bar{U}_t + \varepsilon_t^{\bar{U}} & (8) \\ g\bar{U}_t = (1-\tau_3) g\bar{U}_{t-1} + \varepsilon_t^{g\bar{U}} & (9) \end{cases}$$

Equation (6) assumes that the unemployment rate is determined by the equilibrium unemployment rate ($\bar{U}$) -the NAIRU- and the cyclical unemployment rate (u). The latter is linked to the output gap (y) using equation (7) which is an Okun's law. Equations (8) and (9) determine the equilibrium unemployment rate which is supposed to depend on its steady-state ($\bar{U}^{ss}$) and the variations of the trend ($g\bar{U}$). These equations (8 and 9) allow the equilibrium unemployment rate to vary over time and to deviate from its steady-state.

The third block decomposes the financial dynamics, represented by a financial index FI[2], into a structural component ($\overline{FI}$) and a cyclical component (fi):

$$FI_t = \overline{FI}_t + fi_t \quad (10)$$

The structural component ($\overline{FI}$) is assumed to depend on its inertia and the current and anticipated growth rate of potential output of the economy ($\bar{Y}$). It can also be subject to shocks ($\varepsilon_t^{\overline{FI}}$).

$$\overline{FI}_t = f_1 \overline{FI}_{t-1} + (1-f_1)[(\bar{Y}_{t+1} - \bar{Y}_t) + f_2(\bar{Y}_t - \bar{Y}_{t-1})] + \varepsilon_t^{\overline{FI}} \quad (11)$$

The dynamics of the financial cycle (fi) is supposed to depend on the current and anticipated dynamics of the real cycle (y). Moreover, the financial cycle may be subject to exogenous shocks (ε_t^{fi}).

$$fi_t = f_3 fi_{t-1} + (1-f_3)(y_t + f_4 y_{t+1}) + \varepsilon_t^{fi} \quad (12)$$

The last block describes the reaction of monetary policy which uses the nominal interest rate (rn_t) to achieve its inflation objective (π^{target}) in a forward-looking way.

$$rn_t = \rho_1 rn_{t-1} + (1-\rho_1) * \{rn_t^{neutral} + \rho_2(\pi_{t+4} - \pi_{t+4}^{target}) + \rho_3 y_t\} + \varepsilon_t^{rn} \quad (13)$$

ε_t^{rn} is a monetary policy shock and $rn_t^{neutral}$ is the neutral nominal interest rate. The latter represents the nominal interest rate that would prevail if inflation is equal to its target and the output gap is zero. It is determined using equations (14) and (15) where $rr_t^{neutral}$ is the real neutral interest rate, $(\bar{Y}_t - \bar{Y}_{t-1})$ is the potential growth of the economy. rr_t^{gap} in equation (16) is the real interest rate gap.

$$\begin{cases} rn_t^{neutral} = rr_t^{neutral} + \pi_{t+1} & (14) \\ rr_t^{neutral} = \mu_2 rr_{t-1}^{neutral} + (1-\mu_2) * (\bar{Y}_t - \bar{Y}_{t-1}) + \varepsilon_t^{rr^{neutre}} & (15) \\ rr_t^{gap} = rr_t - rr_t^{neutral} & (16) \end{cases}$$

[2] Appendix 2 describes and presents the construction methodology of the composite financial index used in this work to describe the financial dynamics.

The inflation target evolves according to equation (17) while the real interest rate is implied by Fisher-equation (equation (18)).

$$\pi_t^{target} = \mu_1 \pi_{t-1}^{target} + (1-\mu_1) * \pi_{ss}^{target} + \varepsilon_t^{\pi^{target}} \qquad (17)$$

$$rr_t = rn_t - \pi_{t+1} \qquad (18)$$

The model parameters are estimated for the US economy on quarterly basis using a Bayesian estimation[3] for the period 2000-2017[4]. The results of this estimate as well as the assumptions are presented in Annex 3. The dynamic properties of the estimated model in reaction to different shocks are presented in the next section.

IV. Financial cycle, transmission of economic shocks and monetary policy response

This section first presents the dynamic properties of the model estimated for the US economy by considering the effects of four different shocks: demand shock, inflation shock, monetary policy shock and financial cycle shock[5]. The simulation of these shocks shows the importance of the interaction between the macroeconomic variables and the financial cycle and highlights the role of this cycle in the transmission of shocks. The importance of the financial cycle position in the transmission of shocks and, consequently, for the conduct of monetary policy, is shown through two simulation scenarios of combined shocks. The first scenario simulates the impact of a negative demand shock that coincides with a positive shock of the financial cycle. The second scenario simulates the impact of a negative demand shock of the same magnitude[6] but coinciding with a negative financial cycle shock[7].

Demand Shock (shock to the output gap)

Higher demand leads to pressure on production, which is reflected by a higher inflation and a drop in the unemployment rate. In response to this overheating, a restrictive monetary policy is adopted through the increase of the nominal interest rate. This rise is transmitted to the real interest rate which increases and discourages demand. Being positive, this shock of demand has a favorable effect on the financial dynamics which knows a slight improvement. However, this makes the output gap even more sensitive to changes of monetary conditions. As a result, the effect of rising interest rates on demand is amplified and the shock is absorbed more quickly (see Figure 1).

[3] More precisely, a regularized likelihood maximization according to Ljung (1999) approach. Estimates of unobservable variables are obtained using a multivariate Kalman filter integrated to the estimation approach.

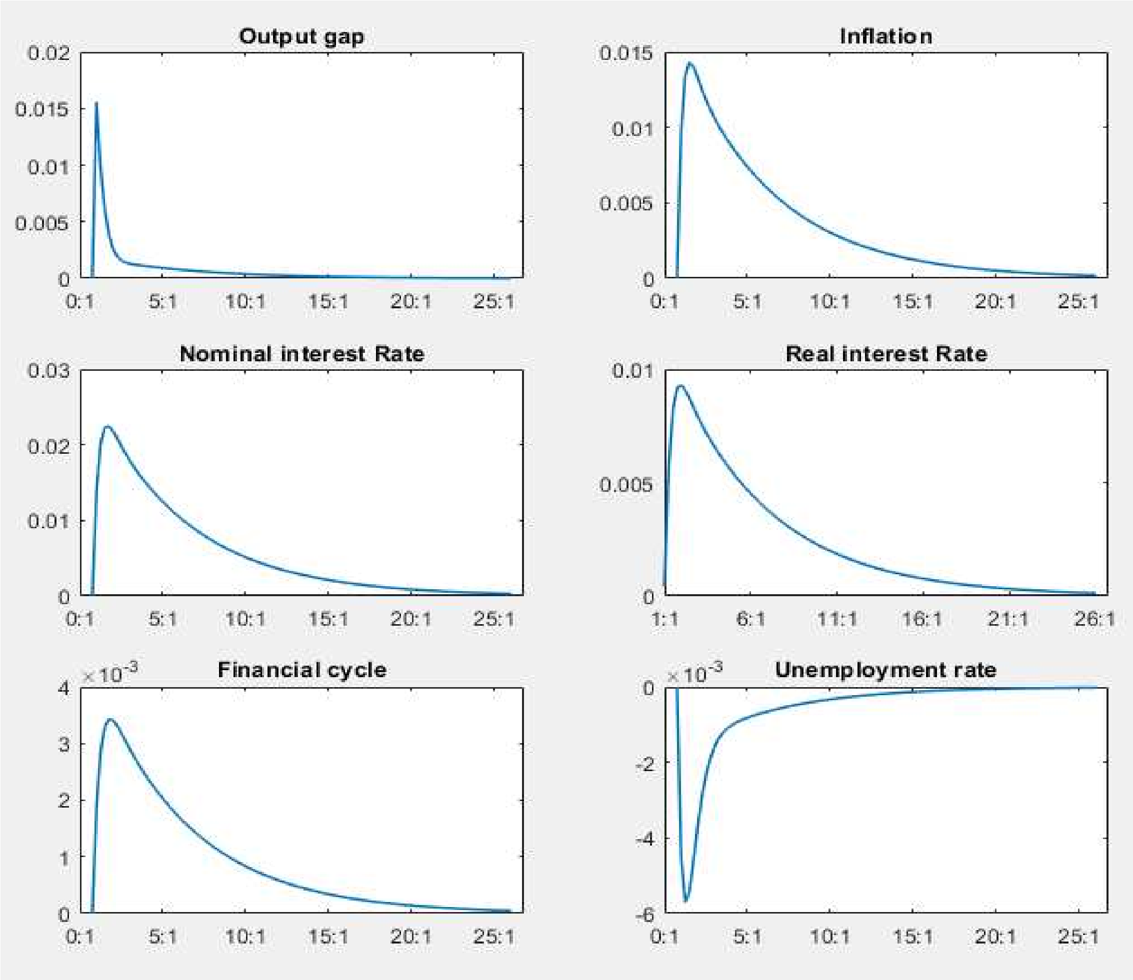
[4] Appendix 1 provides a descriptive table of the data used.

[5] All shocks are positives and simulate a 0.01 increase of the variable.

[6] A 0.01 decrease of the output gap.

[7] In both scenarios, the magnitude of the financial cycle shock is 0.001.

Figure 1: Simulation results of a demand shock

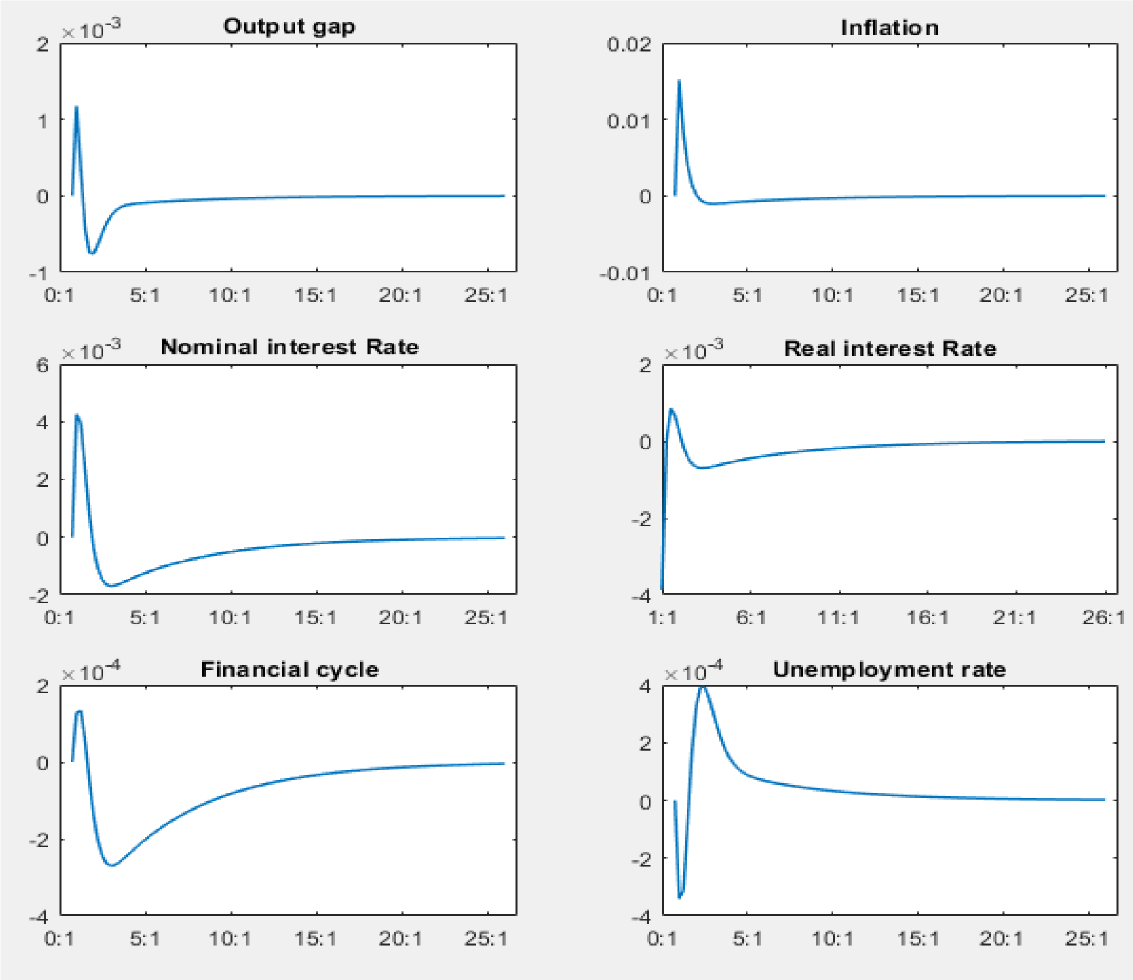


Source: Author.

Inflation shock

The higher inflation leads to an initial decline in the real interest rate, which has a positive impact on demand. This slight improvement in demand allows for a slight absorption of the unemployment rate and leads to even greater inflation. Monetary policy responds to this situation by raising the nominal interest rate until inflation returns to its target. The resulting tightening of monetary conditions discourages demand even more than initial improvement. This allows inflation to return to its target but pushes monetary policy to be more accommodative in order to absorb the negative output gap and avoid disinflation. Here too, the initially positive response of the output gap has a positive impact on the financial dynamics, which makes it possible to absorb the positive output gap more quickly. However, when this gap becomes negative, the agents' expectations deteriorate, and the financial dynamics follows. This reduces the effectiveness of monetary policy, which needs more effort to encourage demand (see Figure 2).

Figure 2: Simulation results of an inflation shock

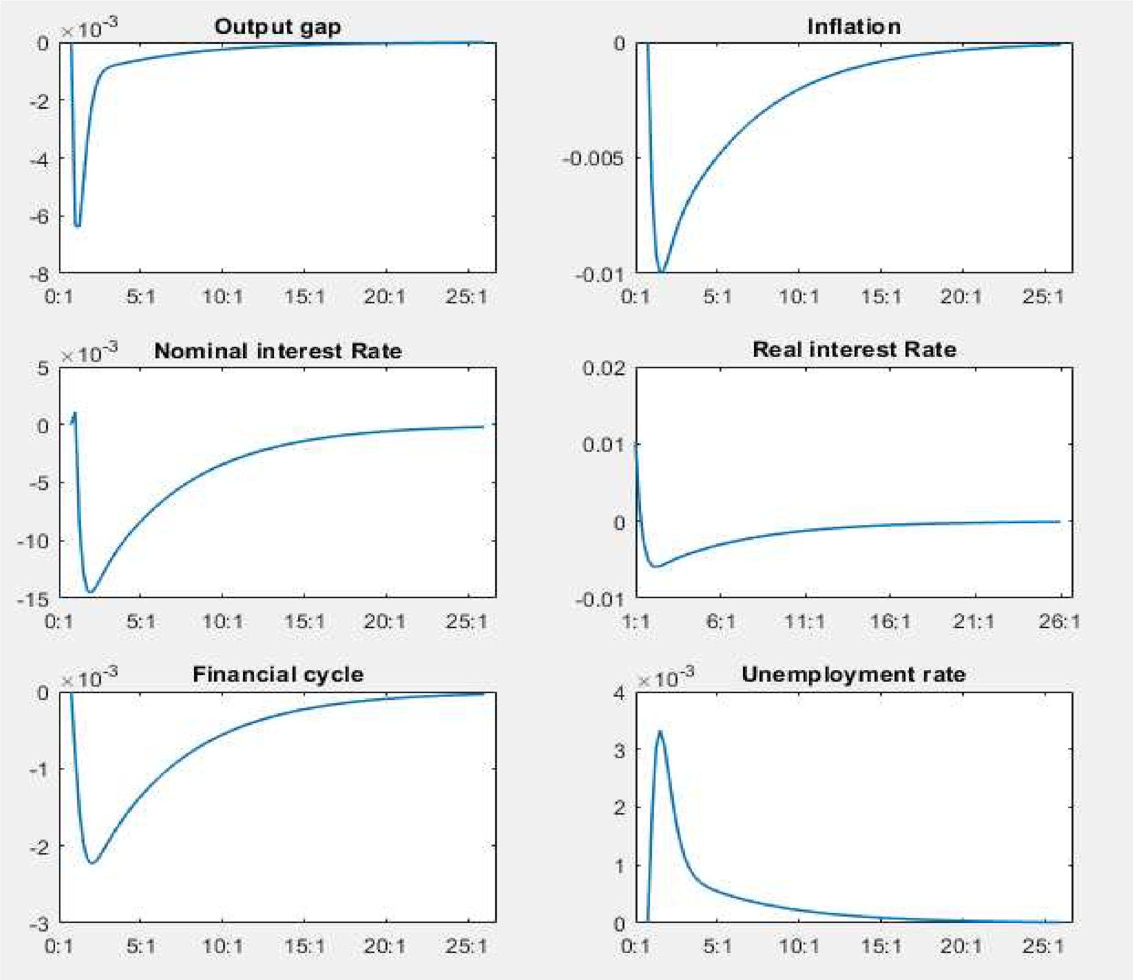


Source: Author.

Monetary policy shock (nominal interest rate shock)

The positive shock of monetary policy causes an instantaneous rise in the real interest rate. This negatively impacts demand, employment and leads to disinflation. A more accommodating monetary policy is adopted to encourage demand and push inflation back to its target. The negative output gap has an adverse effect on the financial dynamics, which is experiencing a slight deterioration. This makes demand less sensitive to improving monetary conditions. As a result, a greater easing effort is initiated by monetary policy (see Figure 3).

Figure 3: Simulation results of a monetary policy shock

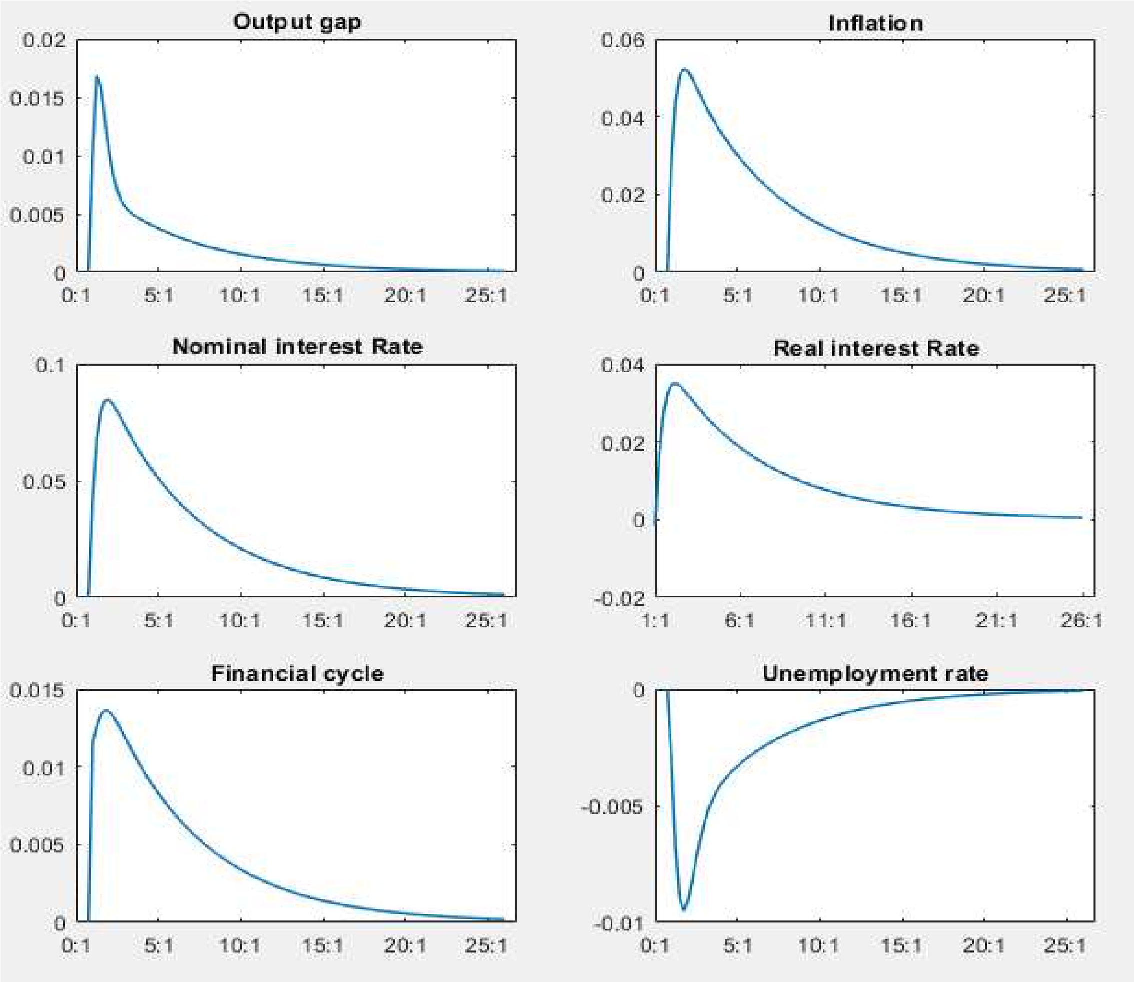


Source: Author.

Financial cycle shock

The positive shock of the financial cycle has a positive impact on demand, which results in a fall in the unemployment rate and an increase in inflation. Monetary policy responds to these inflationary pressures by raising the nominal interest rate. This rise is transmitted to the real interest rate which in turn increases and discourages demand. As the financial cycle is positive in this case, the tightening of monetary conditions is amplified, which makes it possible to absorb the positive output gap more quickly (see Figure 4).

Figure 4: Simulation results of a financial cycle shock

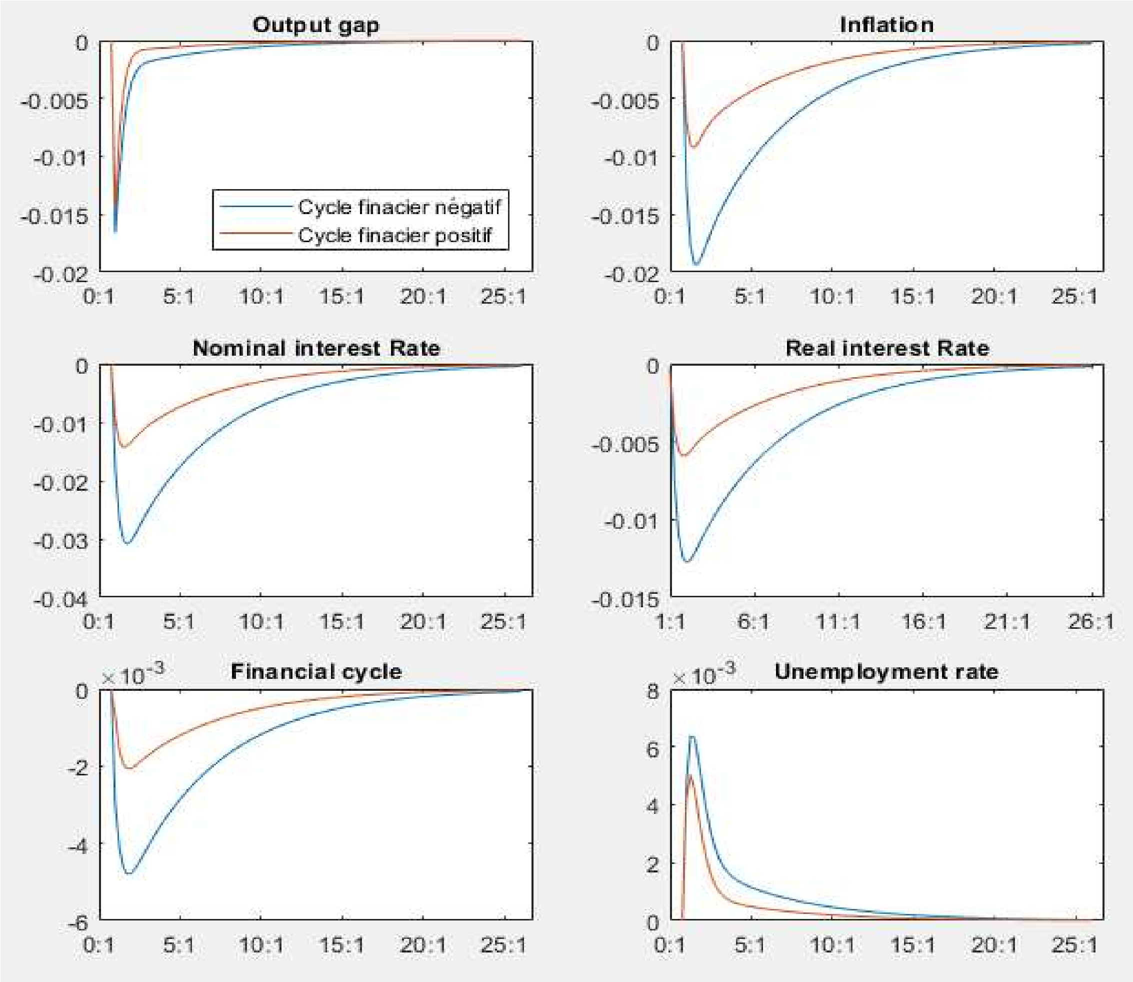


Source: Author.

Negative demand shock: positive financial cycle vs. negative financial cycle

In both cases, the negative demand shock is reflected by an increase in the unemployment rate and a drop in inflation, which encourages monetary policy to become less restrictive. However, the monetary policy effort is less important when the financial cycle is under positive pressure. Indeed, the impact of changes in the real interest rate on the output gap is compressed when the financial cycle experiences negative pressures. This effect represents the pessimism of agents that results in greater risk aversion and more restrictive financing conditions. When the financial cycle is under positive pressure, risk aversion is less important and financing constraints are less restrictive. As a result, the impact of changes in the real interest rate on the output gap is amplified (see Figure 5).

Figure 5: Impact of the financial cycle position in the case of a negative demand shock



Source: Author.

V. Conclusion

This work shows that the positioning of the financial cycle plays a key role in the transmission of economic shocks, in particular, through its impact on the transmission of monetary policy decisions. The impact of these decisions is amplified when the financial cycle is positive, and it is compressed when this cycle is negative. This amplifier/divider mechanism's which plays the financial cycle links the nature of the financial effect on the real activity to the nature of agents' anticipations and not to the nature of the shock. In other words, a negative demand shock will not be systematically amplified. When the financial cycle is under positive pressures, the optimism of the agents makes the initial shock more easily absorbed by a relaxation of monetary policy. In the opposite, the pessimism of the agents when the financial cycle is under negative pressures makes the required relaxation effort of the monetary policy to absorb the initial shock more important.

In terms of the monetary policy conduct's, these results should encourage the monetary authorities to integrate the positioning of the financial cycle as a determining factor in their decisions. The adoption of an analytical framework like the one proposed in this work would allow a better assessing of decisions to raise or lower the interest rate. First, the multiplier/divider mechanism of the financial cycle impacts directly the transmission of monetary decisions. Second, the incorporation of the financial cycle impact on the dynamics of the output gap allows a better appreciation of inflationary and disinflationary pressures. This integration of the financial cycle makes possible to catch the independent impact of this cycle on the balance between the supply and the demand of the economy through its action on the financing conditions.

The results of this work seem intuitive and relevant, but do not claim to be perfect. Indeed, several improvements can be made, in particular, the improvement of the index used to describe the financial dynamics through a more exhaustive and more country-specific index. This work can also be improved by integrating the potential interactions between the real sphere and the financial sphere of the economy which are likely to have an impact on the potential output. Considering the impact of the interest rate on the financial dynamics through its effect on assets prices can also improve this work. Studying these aspects would surely contribute to the improvement of the understanding and may even lead to more interesting results.

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Appendix 1: Used data

The model is estimated on quarterly data of the US economy over the period 2000-2017. The variables used are:

1. **Real GDP**
    - Source: U.S. Bureau of Economic Analysis.
    - Unit: US Dollars.
    - Methodological Details: Chained 2012 prices and seasonally adjusted.
2. **Consumer Price index**
    - Source: Organization for Economic Co-operation and Development.
    - Unit: Index (base year 2010).
    - Methodological Details: Global, seasonally adjusted.
3. **Unemployment rate**
    - Source: U.S. Bureau of Labor Statistics.
    - Unit: Percentage.
    - Methodological Details: Quarterly average of the monthly national unemployment rate, seasonally adjusted.
4. **Nominal interest rate**
    - Source: Organization for Economic Co-operation and Development.
    - Unit: Percentage.
    - Methodological details: 3-month interbank rates for the United States.
5. **Credit and loans granted by commercial banks**
    - Source: Board of Governors of the Federal Reserve System (US).
    - Unit: US Dollars.
    - Methodological details: Seasonally adjusted level at the end of the quarter.
6. **Residential Property Prices Index**
    - Source: Bank for International Settlements.
    - Unit: Index (base year 2010).
    - Methodological Details: Covers all types of existing housing throughout the country. The series is deflated by the CPI.

Appendix 2: Composite Index of Financial Dynamics

In the absence of a variable allowing to describe the financial cycle in an aggregated way, several researchers have proposed composite indexes to describe in a synthetic way this cycle. The principle of these indices is globally the same (see for example Illing and Liu (2006), Lall *et al* (2009), Osorio *et al* (2011), Hollo *et al* (2012), Islami and Kurz-Kim (2013), Duprey *et al* (2017)). In terms of financial variables, these indices are often based on the volume of credit and the price of real estate. Information from the stock market, interbank or bond may also be included if it is considered determinative for a country.

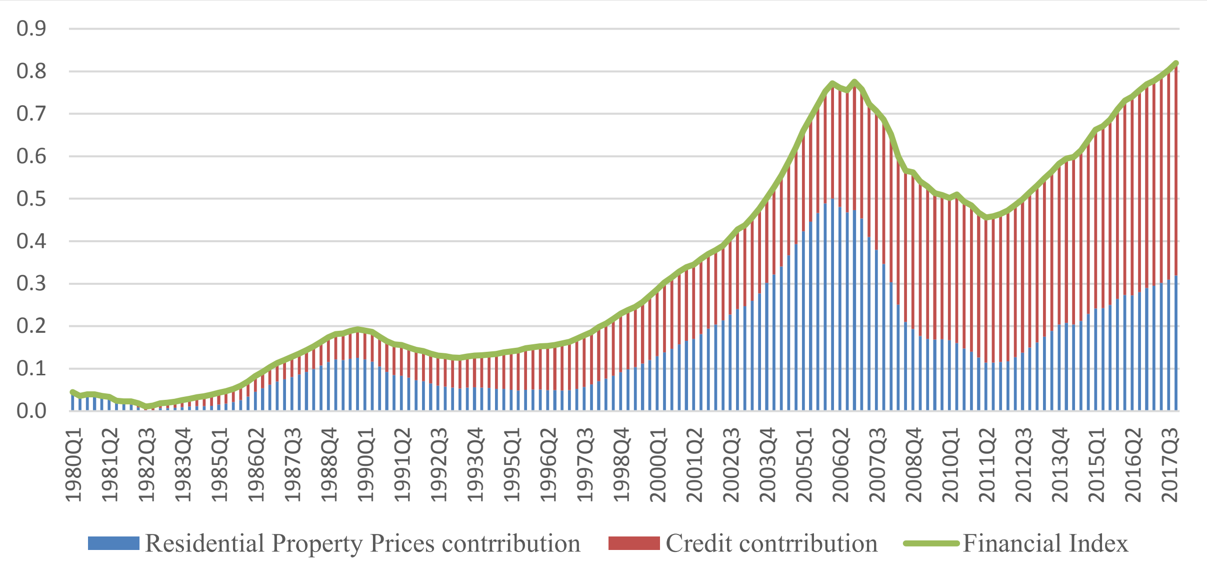
In this paper, we adopt a composite financial index denoted FI (Financial Index). The FI index is the average of the individual financial series (credit volume and real estate price) divided by their respective standard deviations and re-scaled in order to ensure that all the individual components lie between 0 and 1. In practice, the construction of the FI index is done in 3 steps. By adopting the notation $X_{i,j}$ with i for the series and j for the time, the construction of the index is done as follows:

1. The indexed series are divided by their respective variances:
$$Y_{i,j} = X_{i,j}/VAR[X_i]$$
This transformation is done to avoid overweighting highly volatile variables. It can be interpreted as a weighting that is equal to the variance (see Illing and Liu (2006) and Nelson and Perli (2007)).

2. To ensure that all individual observations are between 0 and 1, the minimum value of these observations is subtracted from each of them and the series obtained is divided by its maximum over the period:
$$\tilde{Y}_{i,j} = (Y_{i,j} - \min_j Y_{i,j})/\max_j(Y_{i,j} - \min_j Y_{i,j})$$
Thus, each of the individual components of the index will show 0 for the quietest period and 1 for the most disturbed period. This re-scaling avoids the aggregation bias of the individual components into a single composite index without considering different individual scales.

3. The sum of the individual components (with equal weight) is divided by the number of series included in the index, 2 in our case, so that the value of the FI index is between 0 and 1:
$$FCI_j = \sum_{i=1}^{2} \tilde{Y}_{i,j}/2.$$

Figure 6: Composite index of financial dynamics calculated quarterly for the US between 1980 and 2017



Source: Author.

Appendix 3: Bayesian estimation results of model parameters for the US economy

Parameters	Prior	Low. Bound	Up. Bound	Distribution	Posteriors
λ	0.700	0.200	0.900	Beta	0.371
β	0.300	0.050	3.000		0.084
φ_1	0.900	0.100	0.900		0.418
φ_2	0.500	0.300	0.900		0.656
φ_3	0.500	0.100	0.500		0.256
φ_4	0.300	0.100	0.500		0.278
θ	0.800	0.010	0.900		0.044
τ_1	0.300	0.050	0.900		0.289
τ_2	0.300	0.050	0.900		0.641
τ_3	0.100	0.050	0.900		0.081
τ_4	0.500	0.050	0.900		0.495
ρ_1	0.500	0.010	0.800		0.503
ρ_2	0.600	0.300	0.900		0.736
ρ_3	0.600	0.300	0.900		0.300
μ_1	0.900	0.050	0.900		0.900
μ_2	0.900	0.050	0.900		0.900
f_1	0.900	0.010	0.900		0.900
f_2	0.400	0.100	0.900		0.267
f_3	0.800	0.300	0.900		0.900
f_4	0.600	0.300	0.900		0.315
SD ($\varepsilon^{\bar{Y}}$)	0.010	0.005	3.000	Inverse gamma	0.010
SD (ε^{G})	0.010	0.005	3.000		0.017
SD (ε^{y})	0.100	0.005	3.000		0.615
SD (ε^{π})	0.200	0.005	3.000		0.763
SD (ε^{u})	0.200	0.005	3.000		0.105
SD ($\varepsilon^{\bar{U}}$)	0.010	0.005	3.000		0.010
SD ($\varepsilon^{g\bar{U}}$)	0.100	0.005	3.000		0.122
SD (ε^{rn})	0.200	0.005	3.000		0.201
SD ($\varepsilon^{\pi^{target}}$)	0.100	0.005	3.000		0.099
SD ($\varepsilon^{rr^{neutral}}$)	0.100	0.005	3.000		0.102

SD ($\varepsilon^{\overline{FI}}$)	0.100	0.005	3.000		0.116
SD (ε^{fi})	0.200	0.005	3.000		0.189