Animal Spirits in Open Economy: An Interaction-Based Approach to Bounded Rationality

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Preliminary Draft

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Abstract

In this paper, we develop the waves of optimists and pessimists in a New Keynesian open economy. The model includes the erratic dynamics of inflation and aggregate activity generated by the heterogeneous bounded rational agents according to De Grauwe (2011). In particular, the social interaction effects are incorporated into open economy (Gali and Monacelli (2005)). The interaction between heterogeneous agents provides the basis for bounded rational behavior in a two-country model. As a result, the model is able to describe the herding behavior of investors in open economy. The simulation results suggest that the business cycle goes through periods of high volatility when the large number of optimists or pessimists in one economy strongly affects another economy.

JEL Classification: C63, E31, F41

Keywords: animal spirits; bounded rationality; New Keynesian; two-country model

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1 Introduction

The recent development in the world economy coincides with massive amount of international trade and capital flows. Countries engage in economic activities across borders without being isolated from news in their neighboring countries. Global market integration means that a sudden disturbance of equilibrium in the economy could have spillover effects across countries. With a focus on the complex coordination of economic activities, researchers in open macroeconomics have incorporated aspects of optimizing behavior into general equilibrium, i.e. the so-called Redux model by Obstfeld and Rogoff (1995). Indeed, dynamic stochastic general equilibrium (DSGE) models include the forward-looking behavior of agents which are carried out by microfoundations under rational expectations.

However, the models of optimizing behavior have been criticized on empirical grounds. In the DSGE models, the persistence in the joint behavior of inflation and aggregate activity is induced by serially correlated markup shocks instead of generating endogenous dynamics between countries.[1] This suggests that theoretical New Keynesian models often overlook boundedly rational agents (*or* the backward-looking behavior for a narrow sense of expectation formation processes) for consumption and production in open economy.

To bridge the gap between the model and empirical data, researchers put efforts on developing endogenous persistence in an optimizing framework. The well-known examples are habit formation and price indexation in the behavior of households and firms; see Galí and Gertler (1999), Fuhrer (2000), Amato and Laubach (2003), among others. However, inertia captured by behavioral patterns cannot be easily combined with the structural dynamics in open economy due to its complicated model solution. Furthermore, the complexity of open DSGE models necessitates the need for computationally intensive empirical methods, where e.g. simulation-based methods are often used to estimate the model parameters. These include Markov Chain Monte Carlo method and simulated method of moments; see Fernández-Villaverde and Rubio-Ramírez (2011), Flury and Shephard (2011), as well as Ruge-Murcia (2012), among others.

In particular, many researchers have sought to take into account the market incompleteness in DSGE models, although there has been an increase in the model complexity. For example, the aspects of financial market frictions are called for to make the DSGE model more realistic with respect to transmission channels in the economy.[2] Similarly, this study aims to explore the importance of behavioral aspects of investors in a New Keynesian model, which we consider one of the most important channels in describing the global economy (Akerlof (2002), De Grauwe (2012), and

[1] See also Adolfson et. al (2005) for the role of sticky prices in an open DSGE model from a Bayesian perspective.
[2] Refer to as survey research on DSGE models Tovar (2009) as well as Driscoll and Holden (2014).

Middleton (1986), among others). To see this, we develop an endogenous persistence arising from social interactions in open economy. In other words, the model includes the erratic dynamics of inflation and aggregate activity generated by the heterogeneous bounded rational agents according to De Grauwe (2011). In particular, the social interaction effects are incorporated into open economy (Gali and Monacelli (2005)). The interaction between heterogeneous agents provides the basis for bounded rational behavior in a two-country model.[3] One of main goals in this study is to link the investors' risk-averse behavior (*or* pessimism/optimism) to the real economy with respect to the economic exposure arsing from the financial integration. For example, investors can easily access to recent development of financial derivatives for which bounded rational agents and their interactions in a two-country model amplify irregular and unpredictable patterns in the business cycles. Hence, the model can be used to examine the importance of the monetary transmission mechanism in the two economies. The simulation results suggest that the business cycle goes through periods of high volatility when the share of optimists or pessimists is dominant in the economy.

The paper is organized as follows. In Section 2, we explain the basic framework in an open economy and discuss how demand and supply in the New Keynesian model is influenced by collective behavior of investors emerging from social interactions. In Section 3, using calibrated values for the model's parameters, we simulate persistent behavior of inflation and output based on different values for deep parameters. In Section 4 we examine the importance of animal spirits in open economy and discuss its implications in comparison with previous studies. Finally, we conclude the paper in Section 5. Technical details are relegated to the Appendix.

2 The model

2.1 Symmetric two-country model in canonical form

A world economy in the model comprises two countries. The model incorporates the features of a standard aggregate demand and aggregate supply following Gali and Monacelli (2005). The monetary policy follows *ad hoc* Taylor rule. In contrast with a hybrid New Keynesian model, the persistence and inertia of the model dynamics are mainly driven by the backward-looking terms arising from agents' group behavior. The baseline New-Keynesian Model (NKM) in open economy reads as follows:

[3] Modern macroeconomists often criticize the bounded rationality of heterogeneous agents on theoretical grounds. However, the micro-founded DSGE models with heterogeneous agents may suffer from schizophrenia. On the one hand, the behavioral heterogeneity cannot avoid the complicated parameterization of structural models. On the other hand, interaction-based effects are simplified by the backward-looking behavior from simple behavioral rules, though it is considered an *ad hoc* approach to microfoundation.

$$
\begin{aligned}
x_t &= \mathrm{E}_t(x_{t+1}) - a_1\{r_t - \mathrm{E}_t(\pi_{t+1})\} + a_2\{\mathrm{E}_t(x^*_{t+1}) - x^*_t\} + \varepsilon_{x,t}; \\
\pi_t &= \beta\mathrm{E}_t(\pi_{t+1}) - b_1\{\mathrm{E}_t(x_{t+1}) - \mathrm{E}_t(x^*_{t+1})\} + b_2 x_t - b_3 x^*_t - b_4\{x_{t-1} - x^*_{t-1}\} + \varepsilon_{\pi,t}; \\
r_t &= c_1 r_{t-1} + (1 - c_1)(c_2\pi_t + c_3 x_t) + \varepsilon_{r,t}; \\
x^*_t &= \mathrm{E}_t(x^*_{t+1}) - a_1\{r^*_t - \mathrm{E}_t(\pi^*_{t+1})\} + a_2\{\mathrm{E}_t(x_{t+1}) - x_t\} + \varepsilon^*_{x,t}; \\
\pi^*_t &= \beta\mathrm{E}_t(\pi^*_{t+1}) - b_1\{\mathrm{E}_t(x^*_{t+1}) - \mathrm{E}_t(x_{t+1})\} + b^*_2 x^*_t - b^*_3 x_t - b_4\{x^*_{t-1} - x_{t-1}\} + \varepsilon^*_{\pi,t}; \\
r^*_t &= c^*_1 r^*_{t-1} + (1 - c^*_1)(c^*_2\pi^*_t + c^*_3 x^*_t) + \varepsilon^*_{r,t}
\end{aligned}
$$

where β is discount factor. The parameters a, b, and c are coefficients of IS curve, Phillips curve, and Taylor rule, respectively. The asterisk is used to distinguish foreign economy from domestic economy.[4] Note that two economies are symmetric except for some parameters in the Phillips curve. In other words, we assume that there is no asymmetry in deep parameters between two countries except for the behavior of central banks and price stickiness. For example, the difference in b_2 (or b_3) and b^*_2 (or b^*_3) stems from different degrees of nominal rigidity between the two countries.

Higher interest rate than expected inflation will lower the aggregate demand in the domestic economy ('Fisher equation'). In addition, the expected changes in the output gap of foreign economy can provide upward pressure on domestic economy. The coefficient a_2 is positive because the expected income growth in foreign economy will push up the exports of domestic economy.

The aggregate supply in the domestic economy is derived from profit maximization of individual firms. The producer price index (PPI) inflation depends on its expected future inflation and the output gap in two countries due to the international trade. However, the consumer producer index (CPI) inflation depends on the PPI and the terms of trade (ToT). Hence, in contrast with a closed economy, the Phillips curve in open economy is shifted by some changes in the output gap of the foreign economy. A positive output gap occurring in the foreign economy provide negative pressure into domestic economy. Note that changes in the output of two countries put pressures on ToT, while the marginal cost in domestic firms positively depends on domestic and foreign output levels.

The monetary policy rule is governed by Taylor principle with its reaction coefficients of c_1, c_2, and c_3 ($0 < c_1 < 1$, $c_2 > 1$, $c_3 > 0$). The dynamics of foreign economy is represented by a symmetry of domestic economy in which the corresponding coefficients are indexed with asterisk.

[4]The complete derivation of deep parameters can be found in the literature on standard two-country New Keynesian models. The details of coefficients are given in the Appendix. See also Gali and Monacelli (2005), da Silva (2006), Jang and Okano (2015), among others.

The main feature of bounded rationality is based on a switching rule and forecast performance on the future. The simple heuristic rules specified in expectation formation process follow De Grauwe (2011).

2.2 Interaction-based approach to bounded rationality in open economy

To make the description of the expectation formation processes more explicit, we assume that agents adopt either an optimistic or pessimistic attitude towards movements in the future output gap (in the following indicated by the superscripts O and P, respectively)[5]:

$$\mathrm{E}_t^O y_{t+1} = d_t, \quad \mathrm{E}_t^P y_{t+1} = -d_t \tag{1}$$

$$\mathrm{E}_t^O y_{t+1}^* = d_t^*, \quad \mathrm{E}_t^P y_{t+1}^* = -d_t^* \tag{2}$$

where

$$\begin{aligned} d_t &= \frac{1}{2} \cdot [\nu + \delta \lambda_{y,t}] \\ d_t^* &= \frac{1}{2} \cdot [\nu^* + \delta^* \lambda_{y*,t}^*] \end{aligned}$$

Following De Grauwe (2011), we use the terms of d_t and d_t^* to specify the divergence in beliefs among agents about the output gap in domestic and foreign economies, respectively. The bounded rational agents are uncertain about the future dynamics of the output gap and therefore predict a fixed value of y_{t+1} and y_{t+1}^* measured by ν and ν^*, respectively. The latter can be regarded as the *predicted subjective mean value* of y_t. However, the subjective forecast is generally biased and therefore depends on the volatility in the output gap, i.e. given by the unconditional standard deviations $\lambda_{y,t}$ and $\lambda_{y*,t}^*$. In this respect, the parameters δ and δ^* measure the *degree of divergence* in the movement of economic activity in the two economies. Due to the symmetry in the divergence in beliefs, optimists expect that the output gap will differ positively from the steady state value (which for consistency is set to zero), while pessimists will expect a negative deviation by the same amount. The symmetric two-country model suggests that foreign economy includes the same underlying structure in bounded expectations formation process, but its dynamics is based on different parameter values.

[5]The main goal of this paper is to extend De Grauwe's model to an open economy. The structure of foreign economy is almost identical to the domestic economy except for different parameter values arising from the micro-level behavior of agents. They are indicated by the asterisk.

The expression for the *market forecast* regarding the output gap in open economy is given by

$$\tilde{\mathrm{E}}_t^{BR} y_{t+1} = \alpha_{y,t}^O \cdot \mathrm{E}_t^O y_{t+1} + \alpha_{y,t}^P \cdot \mathrm{E}_t^P y_{t+1} = (\alpha_{y,t}^O - \alpha_{y,t}^P) \cdot d_t \quad (3)$$

$$\tilde{\mathrm{E}}_t^{BR} y_{t+1}^* = \alpha_{y*,t}^O \cdot \mathrm{E}_t^O y_{t+1}^* + \alpha_{y*,t}^P \cdot \mathrm{E}_t^P y_{t+1}^* = (\alpha_{y*,t}^O - \alpha_{y*,t}^P) \cdot d_t^*, \quad (4)$$

where $\alpha_y^O + \alpha_y^P = 1$ and $\alpha_{y*}^O + \alpha_{y*}^P = 1$ hold. The probabilities (α_y^O, α_y^P) and $(\alpha_{y*}^O, \alpha_{y*}^P)$ are based on a stochastic behavior of the agents who adopt a particular forecasting rule. α_y^O (or α_y^P) is regarded as the probability being an optimist (or pessimist) in the domestic economy. The probabilities for the foreign economy are dented by α_{y*}^O (or α_{y*}^P). In the following, we give an explicit description of these probabilities.

First, the selection of the forecasting rules depends on the *forecast performances* of optimists and pessimists U_t^k (with $k = O,\ P$) given by the mean squared error of the forecast performance. The foreign economy is governed by the same behavioral rules with different parameters, where their values are indexed with asterisk. The utility for the forecast performances can be simply updated in every period as (cf. Brock and Hommes (1997)):

$$U_t^k = \rho U_{t-1}^k - (1-\rho)(E_{t-1}^k y_t - y_t)^2; \quad (5)$$

$$U_t^{k*} = \rho^* U_{t-1}^{k*} - (1-\rho^*)(E_{t-1}^k y_t^* - y_t^*)^2, \quad (6)$$

where the parameters ρ and ρ^* are used to measure the memory of agents $(0 \leq \rho,\ \rho^* \leq 1)$. Here $\rho = 0$ suggests that agents have no memory of past observations, while $\rho = 1$ means that they have infinite memory instead. Second, agents can revise their expectations by applying the discrete choice theory under consideration of the forecast performances. The different types of performance measures can be utilized for $(\alpha_{y,t}^O, \alpha_{y,t}^P)$ and $(\alpha_{y*,t}^O, \alpha_{y*,t}^P)$ as follows:

$$\alpha_{y,t}^O = \frac{\exp(\gamma U_t^O)}{\exp(\gamma U_t^O) + \exp(\gamma U_t^P)}, \qquad \alpha_{y,t}^P = \frac{\exp(\gamma U_t^P)}{\exp(\gamma U_t^O) + \exp(\gamma U_t^P)} = 1 - \alpha_{y,t}^O; \quad (7)$$

$$\alpha_{y*,t}^O = \frac{\exp(\gamma^* U_t^{O*})}{\exp(\gamma^* U_t^{O*}) + \exp(\gamma^* U_t^{P*})}, \quad \alpha_{y*,t}^P = \frac{\exp(\gamma^* U_t^{P*})}{\exp(\gamma^* U_t^{O*}) + \exp(\gamma^* U_t^{P*})} = 1 - \alpha_{y*,t}^O \quad (8)$$

where the parameters $\gamma,\ \gamma^* \geq 0$ denote the intensity of choice for domestic and foreign economies, respectively: the self-selecting mechanism is purely stochastic with $\gamma = 0$ (i.e. $\alpha_{y,t}^O = \alpha_{y,t}^P = 1/2$), whereas it is fully deterministic with $\gamma = \infty$ (i.e. $\alpha_{y,t}^O = 0,\ \alpha_{y,t}^P = 1$ or vice versa).

Given the past value of the forecast performance (U_{t-1}^k), we see that the lower the difference between the expected value of the output gap (taken from the previous period, i.e. $\mathrm{E}_{t-1}^k y_t = |d_{t-1}|$)

and its realization in period t, the higher the corresponding forecast performance U_t^k will be. More precisely, if e.g. the forecast made by the optimists is more accurate than the one made by the pessimists, this will lead to a higher level of utility for the optimistic agents, i.e. $U_t^O > U_t^P$ holds. Hence, the pessimists have the incentive to adopt the forecasting rule used by the optimists (i.e., $\mathrm{E}_t^O y_{t+1} = d_t$). Finally, this forecasting rule prevails and the share of pessimists in the market decreases. The same updating mechanism in expectation formation process is applied to foreign economy. Again, the parameter values for the foreign economy are indicated by asterisk.

Following again De Grauwe (2011), we assume that agents will be either so called *inflation (gap) targeters* (tar) or *extrapolators* (ext). In the former case, the central bank anchors expectations by announcing a target for the inflation gap $\bar{\hat{\pi}}$. From the view point of the inflation targeters, we consider this pre-commitment strategy to be fully credible in both economies. Hence, the corresponding forecasting rule becomes

$$\mathrm{E}_t^{tar}\hat{\pi}_{t+1} = \bar{\hat{\pi}}; \tag{9}$$

$$\mathrm{E}_t^{tar}\hat{\pi}_{t+1}^* = \bar{\hat{\pi}}^* \tag{10}$$

with $\bar{\hat{\pi}} = \bar{\hat{\pi}}^* = 0$.[6] The extrapolators instead will expect that the future value of the inflation gap is given by its past value:

$$\mathrm{E}_t^{ext}\hat{\pi}_{t+1} = \hat{\pi}_{t-1}; \tag{11}$$

$$\mathrm{E}_t^{ext}\hat{\pi}_{t+1}^* = \hat{\pi}_{t-1}^*. \tag{12}$$

Note that the market forecast for the inflation gap is similar to the forecast for the output gap in equations (3) and (4):

$$\tilde{\mathrm{E}}_t^{BR}\hat{\pi}_{t+1} = \alpha_{\hat{\pi},t}^{tar}\mathrm{E}_t^{tar}\hat{\pi}_{t+1} + \alpha_{\hat{\pi},t}^{ext}\mathrm{E}_t^{ext}\hat{\pi}_{t+1} = \alpha_{\hat{\pi},t}^{tar}\bar{\hat{\pi}} + \alpha_{\hat{\pi},t}^{ext}\hat{\pi}_{t-1}; \tag{13}$$

$$\tilde{\mathrm{E}}_t^{BR}\hat{\pi}_{t+1}^* = \alpha_{\hat{\pi}*,t}^{tar}\mathrm{E}_t^{tar}\hat{\pi}_{t+1}^* + \alpha_{\hat{\pi}*,t}^{ext}\mathrm{E}_t^{ext}\hat{\pi}_{t+1}^* = \alpha_{\hat{\pi}*,t}^{tar}\bar{\hat{\pi}}^* + \alpha_{\hat{\pi}*,t}^{ext}\hat{\pi}_{t-1}^*. \tag{14}$$

The forecast performances of inflation targeters and extrapolators follow the mean squared forecast-

[6] In this respect (based on an optimal monetary policy strategy), an inflation *gap* target of zero percent implies that the European Central Bank seeks to minimize the deviation of its (realized) target *rate* of inflation from the corresponding time-varying steady state value. Thus the deviation should be zero in the optimum.

ing error in domestic and foreign economies:

$$U_t^s = \rho U_{t-1}^s - (1-\rho)(\mathrm{E}_{t-1}^s \hat{\pi}_t - \hat{\pi}_t)^2; \quad (15)$$

$$U_t^{s*} = \rho^* U_{t-1}^{s*} - (1-\rho^*)(\mathrm{E}_{t-1}^s \hat{\pi}_t^* - \hat{\pi}_t^*)^2, \quad (16)$$

where $s = (tar, ext)$ holds. Finally, we can write:

$$\alpha_{\hat{\pi},t}^{tar} = \frac{\exp(\gamma U_t^{tar})}{\exp(\gamma U_t^{tar}) + \exp(\gamma U_t^{ext})}, \quad \alpha_{\hat{\pi},t}^{ext} = \frac{\exp(\gamma U_t^{ext})}{\exp(\gamma U_t^{tar}) + \exp(\gamma U_t^{ext})} = 1 - \alpha_{\hat{\pi},t}^{tar}; \quad (17)$$

$$\alpha_{\hat{\pi}*,t}^{tar} = \frac{\exp(\gamma^* U_t^{tar*})}{\exp(\gamma^* U_t^{tar*}) + \exp(\gamma^* U_t^{ext*})}, \quad \alpha_{\hat{\pi}*,t}^{ext} = \frac{\exp(\gamma^* U_t^{ext*})}{\exp(\gamma^* U_t^{tar*}) + \exp(\gamma^* U_t^{ext*})} = 1 - \alpha_{\hat{\pi}*,t}^{tar} \quad (18)$$

where $\alpha_{\hat{\pi},t}^{tar}$ and $\alpha_{\hat{\pi}*,t}^{tar}$ denote the probability to be an inflation targeter in domestic and foreign economies, respectively. Economic agents will adopt a target behavior if the forecast performance from the announced inflation gap target is superior to the extrapolation of the inflation gap expectations and vice versa. Note here that the memory (ρ), as well as the intensive of choice (γ), do not differ across the expectation formation processes in terms of the output and inflation gap. In the end, the BR model exhibits purely backward-looking behavior from which we can arrive at the solution to the system numerically by backward-induction, as well as the method of undetermined coefficients, together with the brute force iteration procedure (Binder and Pesaran (1995)).

3 Numerical Simulation

In the section, the model is simulated using a set of different parameter values. In particular, we examine changes in some of behavioral parameters and their effects on the dynamics in open economy. The benchmark values are shown in Table 1.[7] The monetary reaction coefficients are set to same values for two economies. And the memory parameter is set to 0.05 which suggests almost no memory. It is supported by an evidence that memory decays exponentially (Anderson (2001)). Note here that the domestic and foreign economies are denoted by country H and F, respectively.

3.1 Case I: high uncertainty in country *H* and low uncertainty in country *F*

As discussed in the previous section, the animal spirits in open economy are reflected in the group behavior. The behavioral parameters for bounded rational agents provide an approximation to uncertainty about expectation formation processes. For example, the degree of divergence in belief

[7] See the Appendix for the mapping between the coefficients of the model and the deep parameters in open economy.

Table 1: Calibrated values for animal spirits in a two-country model

Parameter	Value	Parameter	Value	Parameter	Value	Parameter	Value
a_1	2	b_2	0.8194	c_1, c_1^*	0.5	ν, ν^*	2
a_2	1	b_3	0.4760	c_2, c_2^*	1.5	δ, δ^*	0.5
b_1	0.2475	b_4	0.25	c_3, c_3^*	1.0	ρ, ρ^*	0.05

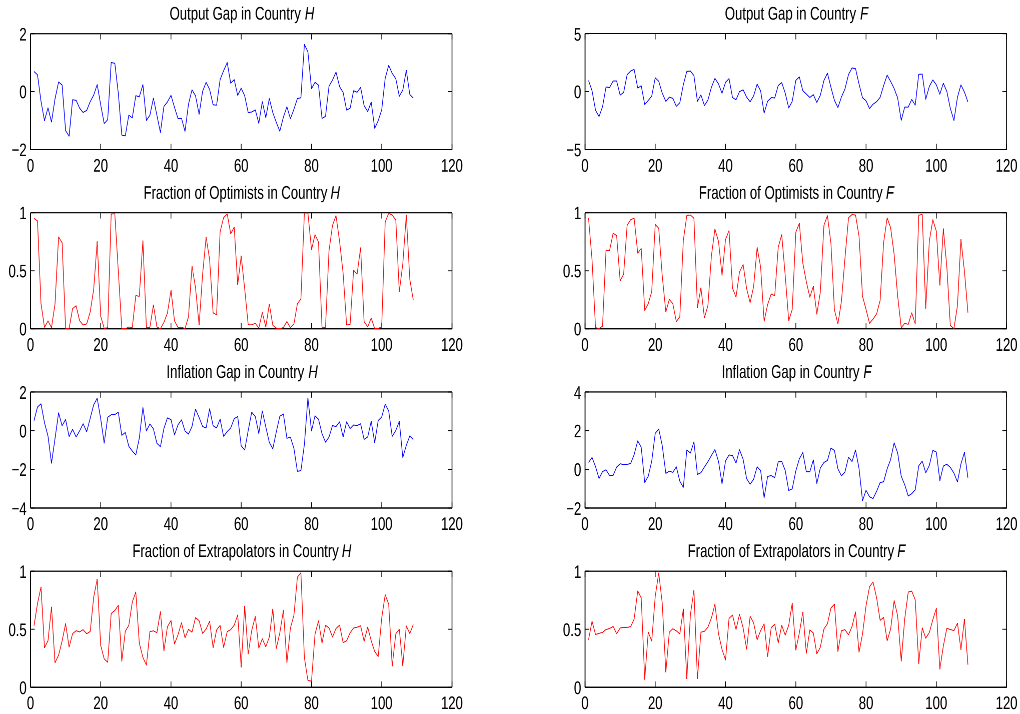
Note: The discount factor β is set to 0.99. The simulations are based on different values for divergence in belief, price stickiness, and trade openness ($\alpha = 0.1, 0.9$).

controls the persistence in extreme opinions at both output and inflation dynamics.

As mentioned earlier, the main goal of simulations is to examine the effects of the behavioral parameters on the model dynamics. Then, one of the most important behavioral parameters is the degree of divergence in belief. We keep other parameters same for the two models, and we consider a moderate degree of trade openness. In other words, two economies engage in same amount of trade activities in which domestic residents buy half of goods from the foreign economy ($\alpha = 0.5$).

The simulated trajectories of output and inflation gap in two countries are shown in Figure 1. The parameters ν and ν^* are set to 2.0 and 0.5 for the countries H and F, respectively. The output gap dynamics in country H is more persistent than country F. This suggests that a large degree of divergence in belief corresponds to a higher degree of persistence the output and inflation dynamics obtains. Even though two countries do not differ in terms of underlying economic structure (i.e., the same values for the deep parameters), the difference in the output and inflation dynamics stems from expectation formation process on market uncertainty. The extreme opinions in the country H persist longer than in the country F, as the perceived uncertainty plays an important role in strengthening their strategy instead of changing their opinions on the economy.

Figure 1: Dynamics in the output and inflation gap in a two-country model



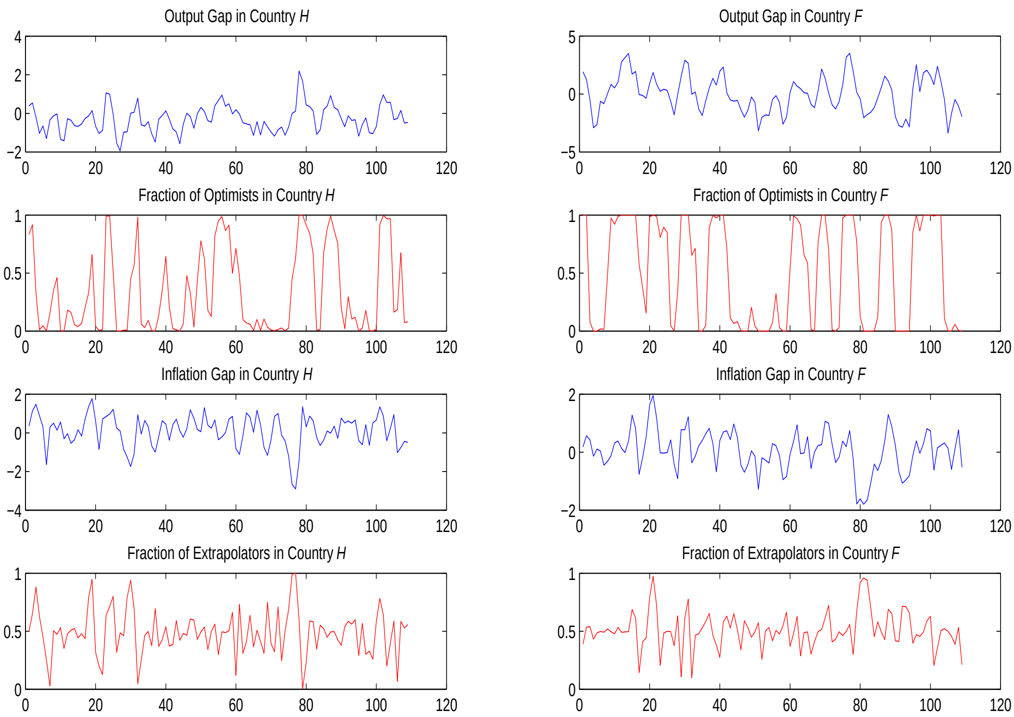
Note: For the country H, the parameter of divergence in belief ν is set to 2.0, while it is set to 0.5 for the country F.

3.2 Case II: same degree of uncertainty, but high price stickiness in country *F*

In this simulation, we investigate the role of price stickiness on the model dynamics. The price stickiness controls the inherited persistence from the output gap in the Phillips curve. Note here that the country F keeps a higher degree of price stickiness than the country H. This produces much flatter slope of the Phillips curve in the country F. Hence, it is shown in Figure 2 that the dynamics of the output gap in the country F remains persistent, while it is being subject to more influence from the country H.

The finding is worth mentioning here because a standard DSGE model with staggered price often fails to produce strong internal mechanism. According to our simulation results, the persistence of output and inflation gap in the country F is attributed to nominal rigidities. Note that the persistent dynamics are also strengthened by the high uncertainty on the future output gap in the country H.

Figure 2: Dynamics in the output and inflation gap in a two-country model



Note: For the country H and F, the parameters of divergence in belief are set to the same value of 2.0. The country F has a higher degree of price stickiness which results in a flatter slope of the Phillips curve (b_2^*=0.5429), while the Philips curve is subject to more influence from the country H (b_3^*=0.4945).

3.3 Case III: low and high degree of trade openness

Now we investigate the effect of trade openness on the dynamics of the output gap and inflation gap. As it is shown in the Appendix, the degree of trade openness influence the inherited and intrinsic persistence in the dynamics of inflation and output. In the simulation, we consider two different degrees of trade openness for two countries, while keeping behavioral uncertainty the same for the countries.

Table 2: Calibrated values for animal spirits in a two-country model

Parameter	Value	Parameter	Value	Parameter	Value
a_1	1.2593	b_2	0.4783	b_2^*	0.1932
a_2	0.2593	b_3	0.1350	b_3^*	0.1447
b_1	0.0728	b_4	0.0735		

Note: The discount factor β is set to 0.99. The monetary reaction coefficients remain same as the previous simulations.

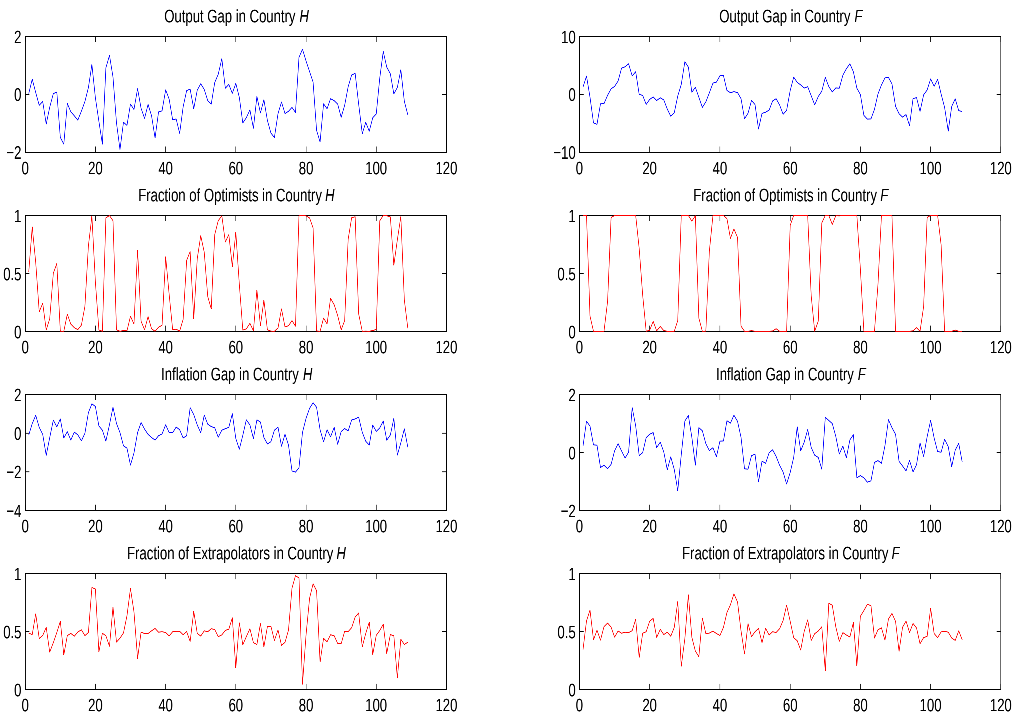
(i) low degree of trade openness ($\alpha = 0.1$)

The spillover effects across countries are now constrained by a low degree of trade openness.

For example, the model can improve the endogenous persistence of the output through economic connectivity, and the high degree of economic uncertainty and price stickiness produce persistent movements in the economy. Hence, a low degree of trade openness prevent the country F from being swayed by the country H, leading to the less persistent dynamics in the output.

Table 2 shows calibrated values for the model with a low degree of trade openness. The low trade integration makes the coefficients in the IS equation and Phillips curve relatively small. The result suggests that the model is less subjected to both internal propagation mechanism and influence from a foreign economy. The simulated trajectories are shown in Figure 3.

Figure 3: Dynamics in the output and inflation gap in a two-country model



Note: For the country H and F, the parameters of divergence in belief are set to the same value of 2.0. The country F has a higher degree of price stickiness.

(ii) high degree of trade openness ($\alpha = 0.9$)

Now we consider a high degree of trade openness between the two economies. The dynamics of inflation and output become more volatile when two economies are closely integrated. The simulation result in Figure 4 shows the underlying interactions play an important role in the model dynamics under a higher degree of trade openness. The result is not surprising: a high degree of trade openness put a pressure on the IS relation and Phillips curve which increase the slope (see Table 3).

Table 3: Calibrated values for animal spirits in a two-country model

Parameter	Value	Parameter	Value	Parameter	Value
a_1	4.8571	b_2	1.6489	b_2^*	1.3638
a_2	3.8571	b_3	1.3056	b_3^*	1.3153
b_1	0.6551	b_4	0.6618		

Note: The discount factor β is set to 0.99. The monetary reaction coefficients remain same as the previous simulations.

Figure 4: Dynamics in the output and inflation gap in a two-country model

Note: For the country H and F, the parameters of divergence in belief are set to the same value of 2.0. The country F has a higher degree of price stickiness.

4 Comparison with other studies

Recent advances in research on behavioral economics and its application to macroeconomic models reflect an existing gap between theoretical models and data.[8] In other words, the inclusion of financial market frictions in DSGE models is a high priority within the macroeconomic channels in the global economy. However, the framework is limited to simple transmission mechanism and its connection to sectors of the economy. As a result, DSGE models are considered to be misspecified to offer guidelines on economic policy (see also Tovar (2009)).[9]

Indeed, only few aspects of financial market distortions have been examined until recently. Examples include balance sheet effects, cost channel, portfolio choice, term premium, among others. For example, firms' balance sheet effects on investment can serve endogenously as the financial accelerator in DSGE models (Bernanke et al. (1999)). The cost channel between countries can be used to generate propagation mechanism in the global economy (Ravenna and Walsh (2006)). Differences in home and foreign portfolio may have significant effect on equity portfolios under nominal price stickiness (Engel and Matsumoto (2005)). Furthermore, the relation between term premium and the economy can be investigated within this context (Rudebusch et al. (2006)).

This study is motivated to explain the financial market frictions much like the above studies on the structure of DSGE models. But the approach is based on social interaction effects between countries such that bounded rational agents act as a main driver of market incompleteness in open economy. As shown in the Section 2, the baseline open DSGE model does not include lagged terms in the IS and Phillips curve. As a result, the model becomes purely forward-looking without considering the bounded rational behavior of agents. By introducing performance measures of optimists and pessimists, the model links the structural economy to international financial markets based on backward-looking aspects of investors. In other words, a behavioral channel between countries can be used to strengthen a risk-averse behavior of bounded rational agents through international trade and investment.

In addition, global market can be decentralized according to which the agents over- or under-react to the state of the economy. The dynamics is endogenously combined to the structural microfounded models, where we consider the behavior of investors may generate local instability of the equilibrium in the model.

[8]Behavioral macroeconomics and the empirical deficiency of New Keynesian models are surveyed by Driscoll and Holden (2014).

[9]One of the recent development in research is to integrate financial sector into the real markets. These include Lengnick and Wohltmann (2013), as well as Biondi and Righi (2013).

5 Conclusion

The global economy is complicated by many aspects of international trade and investment across countries. The distortions might stem from e.g. the existence of incomplete markets, cost channel and trade openness. In this study, we put an emphasis on behavioral perspective and the perceived uncertainty of heterogeneous agents on the model dynamics. In other words, the interactions arsing from forecast performance between heterogeneous agents could generate a high degree of uncertainty on economic activities in open economy.

To show this, we construct an artificial open economy where two countries are constrained by social interactions between heterogeneous investors. Our simulation results show that social interaction effects serve as an transmission channel for market integration in the open economy. Indeed, the market integration puts pressure on economic activities which are constrained by the uncertainty of investment. To show this, we examine the effect of the social interactions between boundedly rational agents on the joint behavior of inflation and output within two countries.

In addition, our simulation results can be used to set the stage for future research on the DSGE models. For example, the estimation of the behavioral parameters from real data can be considered a high priority on current research. For example, Jang and Sacht (2015) make an estimation of De Grauwe model by using SMM from Euro Area data, and found that the backward-looking behavior and bounded rationality play an important role in the approximation of the model to empirical data. Similarly, simulation-based methods can be used to bridge the gap between the model dynamics and real data. Another research direction includes the extension of the expectation formation process in which forecast performance in one country depends on the mean squared forecast errors from another economy. This kind of extension can be explored to analyze the effects of complicated economic dynamics on integrated economies.

Appendixes

A: Matrix form of open economy

We denote by z_t the state vector of $[\ x_t\ \pi_t\ r_t\ x_t^*\ \pi_t^*\ r_t^*\ ]'$. Then, the structural model of a symmetric open economy can be rewritten in canonical form:

$$A\mathtt{E}_t z_{t+1} \ + \ Bz_t \ + \ Cz_{t-1} \ = \ 0, \tag{19}$$

where:

$$A = \begin{bmatrix} 1 & a_1 & 0 & a_2 & 0 & 0 \\ -b_1 & \beta & 0 & b_1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ a_2 & 0 & 0 & 1 & a_1 & 0 \\ b_1 & 0 & 0 & -b_1 & \beta & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix},$$

$$B = \begin{bmatrix} -1 & 0 & -a_1 & -a_2 & 0 & 0 \\ b_2 & -1 & 0 & -b_3 & 0 & 0 \\ (1-c_1)\cdot c_3 & (1-c_1)\cdot c_2 & -1 & 0 & 0 & 0 \\ -a_2 & 0 & 0 & -1 & 0 & -a^* \\ -b_3^* & 0 & 0 & b_2^* & -1 & 0 \\ 0 & 0 & 0 & (1-c_1^*)\cdot c_3^* & (1-c_1^*)\cdot c_2^* & -1 \end{bmatrix},$$

$$C = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 \\ -b_4 & 0 & 0 & b_4 & 0 & 0 \\ 0 & 0 & c_1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ b_4 & 0 & 0 & -b_4 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & c_1^* \end{bmatrix}.$$

The method of undetermined coefficients and iterative methods can be used to solve the system of equations. This solution indicates the equilibrium values of the observable variables in the system.

B: The coefficients of deep parameters in a two-country model

Table 4: Calibrated values for animal spirits in a two-country model

Parameters	Description	Value
σ	Risk aversion	1.0
η	Elasticity of substitution between goods	2.0
φ	Labor disutility	3.0
θ_H	Calvo lotteries in domestic price	0.75
θ_F	Calvo lotteries in foreign price	0.9
$\phi_\pi = \phi_\pi^*$	Taylor rule inflation	1.5
$\phi_y = \phi_y^*$	Taylor rule output growth	1.0
$\phi_r = \phi_r^*$	Interest rate smoothing	0.5

Note: The discount factor β is set to 0.99. The simulations are based on different values for trade openness ($\alpha = 0.0, 0.1, 0.6, 0.9$).

$$
\begin{aligned}
\kappa_H &= (1-\theta_H)\cdot(1-\theta_H\cdot\beta)/\theta_H;\\
\kappa_F &= (1-\theta_F)\cdot(1-\theta_F\cdot\beta)/\theta_F;\\
\omega_2 &= 2\cdot\alpha\cdot(1-\alpha)\cdot(\sigma\cdot\eta-1);\\
\omega_4 &= 4\cdot\alpha\cdot(1-\alpha)\cdot(\sigma\cdot\eta-1);\\
\varsigma &= (\omega_2+1)\cdot\sigma+(\omega_4+1)\cdot\varphi;\\
a_1 &= (\omega_4+1)/\{(\omega_2+1-\alpha)\cdot\sigma\};\\
a_2 &= (\alpha+\omega_2)/(\omega_2+1-\alpha);\\
b_1 &= (\beta\cdot\alpha\cdot\sigma)/(\omega_4+1);\\
b_2 &= \{\alpha\cdot\sigma\cdot(1+\beta)+\kappa_H\cdot\varsigma\}/(\omega_4+1);\\
b_3 &= \sigma\cdot\{\alpha\cdot(1+\beta)-\kappa_H\cdot\omega_2\}/(\omega_4+1);\\
b_4 &= (\alpha\cdot\sigma)/(\omega_4+1);\\
b_2^* &= \{\alpha\cdot\sigma\cdot(1+\beta)+\kappa_F\cdot\varsigma\}/(\omega_4+1);\\
b_3^* &= \sigma*\{\alpha*(1+\beta)-\kappa_F*\omega_2\}/(\omega_4+1);
\end{aligned}
$$

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