SOME MACROECONOMIC IMPLICATIONS OF BEHAVIORAL BIASES

Aragón, Nicolas
Some Macroeconomic Implications of Behavioral Biases

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Abstract

We include behavioral biases into a general equilibrium framework. Agents learn among different mental models about the process generating disposable income. We use a combination of Barberis et al (1998) and Mullainathan (2002) to generate waves of optimism, pessimism, overreaction and underreaction in aggregate macroeconomic behavior. This generates a following the trend type of behavior as in Heymann et al (2001). We use the model to explain three stylized facts found in developing countries that standard models cannot currently explain, namely i) countercyclical trade balance, ii) high consumption to output volatility and iii) the presence of sudden stops. The policy implications are analyzed and there is room for a welfare improving countercyclical fiscal policy that, in case of a contraction in aggregate demand, will not only boost present aggregate demand but also causes agents to be optimistic about the future and to start investing and consuming.

I. Introduction

Contributions by Taussig (1911), Pigou (1929) and ultimately Keynes (1936) emphasized the role of expectations in generating and amplifying business cycles. John Maynard Keynes coined the phrase “animal spirits” to describe a range of emotions, human impulses, enthusiasms and misperceptions that drive and ultimately unwind economies.

The role of biased expectations vanished from macroeconomic research after the Rational Expectations Revolution. In DSGE models the term animal spirits (Azariadis 1981, Howitt and McAfee 1992, Farmer and Guo 1994) is used interchangeably with sunspots (Cass and Shell 1983) and self-fulfilling prophecies (Azariadis 1981, Farmer 1993). However, in the few last years there has been a comeback to the idea that expectations might not be as rational as mainstream theory assumes. Notable examples are Shiller and Akerlof (2009), Farmer (2010) and the “news about the future” literature, within which Jaimovich and Rebelo (2009) is the most important reference for the matters of this paper. Other papers, like Scheinkman and Xiong (2003) explain asset prices bubbles with overconfident investors in a partial equilibrium framework. This work takes the latter literature one step further, generalizing this biases to the economy as a whole, and also allowing learning considerations.

The news literature has its roots in early work by William H. Beveridge (1909), Arthur Pigou (1929), and John Maurice Clark (1934). The idea is that news shocks change agents expectations
about the future affecting their current investment, consumption, and work decisions. Paul Beaudry and Frank Portier (2004, 2007), Lawrence Christiano, Cosmin Ilut, Roberto Motto, and Massimo Rostagno (2007) and Jaimovich and Rebelo (2007) are examples. Their interpretation of business cycles is that high expectations about earnings growth driven by the prospects of new technologies lead to high levels of investment and to an economic boom. When the new technologies fail to live up to what was expected, investment falls, and a recession ensues.

Jaimovich and Rebelo (2007) focus their attention on two biases emphasized in behavioral finance: optimism and overconfidence. The expectations of optimistic agents are biased toward good outcomes, while overconfident agents overestimate the precision of the signals that they receive. In an estimated version of their model they find that both expectation shocks and overconfidence can increase business cycle volatility, while preserving the models properties in terms of comovement and relative volatilities. In contrast, optimism is not a useful source of volatility in their model.

This paper models behavioral biases in a macroeconomic setup using the learning literature and is then used to analyze whether these can be a source in generating some stylized facts that characterize developing economies and to analyze theoretical implications regarding fiscal policy. The biases in this paper are broader than those present in Jaimovich and Rebelo (2007) and are of a dynamic nature generating a "following the trend" sort of behavior, as in Heymann and Sanguinetti (1998) and Heymann et al (2001). A parallel to the news literature can be made by arguing that in this model (perceived) news are "endogenous".

In the past few decades learning models in macroeconomics have appeared in the literature. Nevertheless, those models are not widely used. It is believed that these models allow too many degrees of freedom to the economist and therefore the models are not falsifiable and that expectations can be model-inconsistent. In this paper we allow temporary departures from rationality that are well documented in experimental economics imposing a certain discipline on the expectations formation mechanism. That is, we only accept some deviations of full rationality caused by the “passions and fears” of the agents.

We model an expectation formation setup similar to Barberis, Shleifer and Vishny (1998). Experiments have shown that there is a tendency to understand events as “typical” or representative of some specific class an to ignore the actual laws of probabilities. Agents use heuristics instead of a complete calculation of the objective probability. In other words, an agent assess the probability of an uncertain event by the degree to which it is similar to other phenomena which reflects similar properties to the observed process. As documented by Tversky and Kahnemann, people see patterns in random sequences. This behavioral heuristic is known as representativeness. Also, there is another phenomenon called “conservatism”, which is a slow updating of expectations in light of new evidence. Underreaction is consistent with this bias, because agents disregard the full information content and believe some realizations of stochastic values (under some conditions for the prior estimates) to be of a temporary nature.

In our model, there are three different mental models regarding productivity innovations behavior: trend-following, reversionist an the true model. Under the trend-following model agents will assign a high probability to a positive future productivity shock after observing a positive shock
today, and vice versa. In the reversionist model, agents will assign a low probability to a positive future productivity shock after observing a positive shock today and vice versa. The true model for the productivity innovation is white noise. Agents will incorrectly think that there is a pattern in the observed realizations and will update the likelihood that one of the models is generating the process. This will generate waves of optimism, pessimism, overreaction and underreaction. I analyze two learning mechanisms: Bayesian Learning and Bayesian Learning with “mental categories”. Differently to other models in the learning literature (surveyed by Evans and Honkapohja (2001)) where agents learn in the space of parameters, in this model agents will learn in the space of models.

In the Bayesian update setup, agents will learn about which mental model is more likely to be generating the observed productivity story and assign probabilities to each one. Specifically, when a positive productivity innovation is followed by another positive surprise, the agent raises the likelihood that he is in the trending regime, whereas when a positive surprise is followed by a negative surprise, the investor raises the likelihood that he is in the mean-reverting regime. In the same way, after a long period of good news, one bad realization does not change much the weight assigned to the trending model. The expectation about tomorrow’s productivity is weighted average among the expectations by the different models. Mullainathan (2002) analyzes categorical thinking. Differently to the representativeness bias, he models the categories as constraining the distribution that can be chosen from the full set of mental models. This is consistent as investors thinking of a market as “bull” or “bear” market, or, in the case of this paper, a whole economic system thinking as a “growing” or “stagnated” economy, consistent with optimism and pessimism respectively. When one particular model is more likely to be the one generating the stream of observed productivity shocks agents will change the category they form expectations with, thus generating switches in the expectational regimes. Expectations are, in this sense, “sticky”. This is, of course, a simplification of Bayesian reasoning when agents can hold finite set of posteriors and implies underreaction to news in certain ranges and overreaction when “categories switch”.

Aguiar and Gopinath (2004) document three stylized facts in developing economies: i) High consumption volatility, ii) countercyclical current account and iii) the presence of sudden stops. They explain these stylized facts using shocks to the trend growth, that is, a non stationary shock. Garcia Cicco et al. (2010) explain these facts with a combination of stationary shocks to preferences, interest rates (through country-premiums) and using a different debt elasticity of country risk premium.

The described expectation formation mechanism is embedded in Mendoza (1993) seminal open economy model in order to account for these stylized facts. In the standard RBC model the correlation of trade balance to output is a random walk. In this model, however, the correlation is positive since a high productivity today boosts optimism about future income and therefore boosts consumption above their true level. The high consumption volatility fact that is present in developing countries can also be explained with a misperception about future output as will be shown in this paper. However, we believe that the main explanation lies in the incomplete markets that are pervasive in developing countries, that makes it difficult to smooth consumption. However, our numerical exercise show that the misperception can certainly can contribute to this pattern, even in countries with a well developed credit market. This model can also explain sudden stops endogenously. Sudden stops are a pervasive phenomenon characterized by a sudden loss of access
to international capital markets, leading to a reversal in the current account and a collapse in domestic production. The frictionless RBC model and sticky-prices DSGE models cannot account for this phenomenon, because capital markets should provide the means for the economy to borrow in order to smooth consumption and to diminish the risk of idiosyncratic shocks.

The literature on sudden stops modeled the capital markets as subject to financial market imperfection and informational frictions. According to the survey by Arellano and Mendoza (2002) there are two rough categories of financial transmission mechanisms. Firstly, a group of studies (Calvo, 1998; Izquierdo, 2000, among others) focus on the transmission mechanism driven by a debtors ability to pay. Debtors are willing to repay their debts but their ability to do so is threatened some exogenous shock. Secondly, another branch of the literature (Eaton and Gersovitz, 1981; Bulow and Rogoff, 1989, among others) focuses on debtor’s willingness to pay. Debtors decide optimally to renege on their debts when the expected discounted utility of defaulting, net of default penalties, exceeds the expected lifetime payoff of paying. A Problem with the literature is the focus on the transmission mechanisms relying on exogenous shocks to some variables to generate the reversal in capital flows. The peso problem associated with these states is not addressed in the models, assuming “zero measure” probability for these shocks. Our setup can trigger a sudden reversal of expectations because while under an optimistic mental framework a certain level debt can be sustainable, it might not be when optimistic expectations are corrected to the original or the pessimistic model. Overoptimistic economies will take debt assuming a higher future productivity and output, expectations that will be frustrated when these are not realized. The level of debt taken during optimistic booms can be high enough as to prompt a default.

It is important to emphasize that the logic behind our model and Aguiar and Gopinath’s is the same, but the difference is the logic that underlies it. In their model agents perfectly forecast the future and are subject to shocks and in our model, agents do not know the actual probability distribution and interpret the observed shocks, thereby making the misforecast endogenous.

Our explanation of endogenous misforecasts opens the possibility of some welfare enhancing policy intervention. Therefore, the model is simplified (for computational ease) and used to analyze theoretically the simplest case of non distortionary fiscal policy. In our model there is room for the desirability of countercyclical government action.

Since Keynes’ General Theory, it is commonly argued that an increase in public expenditure generates an increase in output. This is a strong correlation in the data. However, in a standard RBC model, an increase in government expenditure leads to a decline in output. Therefore, to explain the increase in output when expenditure is high, the standard RBC model relies on a concomitant increase in productivity when the government decides to spend more. We believe this to be a mistake. The optimal taxation literature (Lucas and Stokey, 1983; Chari, Christiano and Kehoe, 1991; Chari and Kehoe, 1999) identifies the tax profile that minimizes the associated distortionary costs and as a consequence, the tax rate should be smooth and respond very little to shocks. This conclusion is derived in models in which agents fully understand the problem faced by the government and have model consistent expectations. We intend to analyze the case of inconsistent expectations, when the macroeconomic trajectory is not sustainable.

Optimal fiscal policy literature adheres to the rational expectations hypothesis thereby ignoring the possibility of widespread foresight biases. We argue that anticyclical fiscal policy might prevent
an excessive contraction in aggregate demand when expectations are not validated as in Heymann and Kawamura (2009). Our model provides the same policy prescription in an infinite horizon model with endogenous expectations. In our model, agents will also form behavioral expectations on future net transference rates (i.e taxes) and will have biased expectations towards future disposable income (this is, productivity and net transferences). The government can alter disposable income by lowering taxes, thereby boosting actual consumption and investment by restoring confidence over future disposable income. Fiscal policy not only boosts aggregate demand today, but also restores confidence on future income. Another conclusion that arises from the model is that fiscal policy is more effective if applied quickly, at the beginning of the downward trend, because otherwise the agents will enter in a pessimist mental model and a bigger and longer stimulus will be necessary to restore confidence. As Franklin D. Roosevelt stated “government spending acted as a trigger, a trigger to set off private activity”. This model shows how confidence can be boosted by altering government spending in the spirit of Keynes’ ideas.

Section II presents some evidence on behavioral economics and argues why this is might be important for macroeconomic research. Section III presents the model and the expectation formation mechanism. The first subsection shows the open economy model and is used to explain developing countries’ stylized facts. The second subsection analyzes non distortionary fiscal policy in a simplified model. Section IV concludes and points the lines of future research.

II. Some Evidence

There is extensive experimental evidence on the systematic biases when people form beliefs, collected mostly by psychologists. We will review the cornerstones of the experimental research which are relevant to the biases used on this paper.

The representativeness heuristic was first presented by Kahnemann and Tversky (1973). The representativeness heuristic means that agents evaluate the probability of an event A being generated by an event B through an evaluation of the degree by which A reflects the essential characteristics of B. They survey a number of people and asked them to assign probabilities to different questions and show that there is a tendency to two biases: the base rate neglect and the sample size neglect. Sample size neglect means that people normally use a small sample assuming it is representative of the whole process when making a decision. This is illustrated in the gambler’s fallacy. After ten red draws in a roulette, the agent believes that a “black draw” is due. Kahneman and Tversky gave their subjects the following information:

“Tom W. is of high intelligence, although lacking in true creativity. He has a need for order and clarity, and for neat and tidy systems in which every detail finds its appropriate place. His writing is rather dull and mechanical, occasionally enlivened by somewhat corny puns and by flashes of imagination of the sci-fi type. He has a strong drive for competence. He seems to feel little sympathy for other people and does not enjoy interacting with others. Self-centered, he nonetheless has a deep moral sense.”

The subjects were then divided into three groups. The first group was asked how similar Tom W. was to a student in one of nine types of college graduate majors (business administration,
computer science, engineering, humanities/education, law, library science, medicine, physical/life sciences, or social science/social work). Most subjects associated Tom W. with an engineering student, and thought he was least likely to be in social sciences. The second group was asked to estimate the probability of Tom W. being a graduate student in each of the categories and the results were consistent with the previous group: a very high probability was assigned to him being an engineering student. The third group was asked to estimate the proportion of first year graduate students in each of the nine majors. The important result of this experiment is that the second group’s probabilities were approximated by how much Tom W. looks to the stereotypical major and less on the base rate of being an engineer (which are very few). In other words, the subjects disregarded the base probability.

Conservatism was first experimentally documented by Edwards (1968). This bias states that people normally overemphasize the base rate. That is, once they made up their mind they don’t easily change their views. In the experiment there are two boxes. The first one contains 3 blue balls and 7 red balls. The other one contains 7 blue balls and 3 red balls. There is a random draw of 12 balls with replacement from one of the boxes yielding 8 red and 4 blue and the subjects are asked to state the probability of the first box being the one used to make the draws. Agents estimated an average of 0.7, while the true probability is 0.97, overestimating the base rate of 0.5.

Weinstein (1980) collects evidence on optimism and overconfidence. For example, over 90 percent of the surveyed people believe they are above average in several dimensions such as driving and interpersonal relations skills. Similarly, there is a substantial “planning fallacy”. This means that people normally believe they will finish a task much sooner.

These biases are widely studied in microeconomic setups and have been successfully applied to explain observed behavior in portfolio selection, aggregate stock market, the cross-section of average returns and individual trading behavior (Barberis and Thaler, 2002).

As should be clear, all these biases have been tested in individual decision making. There has been no attempt to analyze if these biases can be generalized to a group of agents, which is of relevance to macroeconomics and this paper in particular. There is a belief that most often than not behavioral biases vanish when subjected to the discipline of the market. As Levitt points out, there are many reasons (the scrutiny, the expectations, the actors involved, etc.) to suspect that these laboratory findings might fail to generalize to real markets. Of course, this paper won’t attempt to prove that behavioral biases are pervasive in macroeconomics, but this section will only highlight some evidence that we think suggests this can be an important factor in business cycles.

Reinhart and Rogoff (2009) point out the enthusiast opinions of international organisms and financial markets regarding economies like Mexico (1994), Korea (1997) and Argentina (2001) not long before the crises and therefore a quantitative measure to define when a country is “graduating” from an emergent market status cannot be done solidly using market sentiment. It seems that the current problem in Europe, specially in Portugal and Greece is similar in essence. This point has been emphasized by Heymann et al (2001) in the past. They point out some cases where they argue there have been large scale macroeconomic forecast revisions. The cases they cite are Argentina, Mexico, Uruguay and Chile during the early eighties, and Argentina during the nineties. They
argue that these ups and downs in economic behavior were in turn with expectations. Changes in projected growth rates and in terms of borrowing lead to substantial movement in individuals’ perceived wealth. Agents had reasons to believe that their incomes would grow faster than in the past and foreign lenders were willing to provide financing on the basis of optimistic evaluations of the economy. After the crisis it makes sense to believe that some expectations were frustrated.

The following graph shows IMF’s forecasts on Greek output. The different forecasts show the updating in future expectations and the systematic overestimation of future income and wealth. According to the most standard economic theory this should impact on the agents’ control variables. In the context of this paper this can be understood as an overly optimistic mental framework due to a series of positive income shocks, which did not materialize. We find this pattern very suggestive of the presence of biased and overly optimistic expectations.

A word of caution, however, should be noted. The stylized facts that Aguiar and Gopinath (2004) report and that this model can successfully explain are found in developing countries. An argument about why these behavioral patterns would be more prominent in those countries should be made, although recent experiences in developed countries (Greece, Spain, Portugal) might suggest that these can be prevail even there.

There is some empirical evidence on discount rates by wealth classes. Part of the problem, of course, is the difficulty in measuring the rate at which people trade off future versus current consumption. Pender and Walker (1990) use experimental games with hypothetical questions and real payoffs to estimate the discount rates. They found that the rate of time preference was in-
versely related to wealth, and that rates exceeding 100 percent were common among the poorest members of the sample. Holden, Shiferaw and Wik (1998) also used hypothetical questions in surveys conducted in rural areas of Indonesia, Ethiopia and Zambia. The questions were framed by asking respondents how much they would need to be paid today in order to forego a given amount of money to be paid in one year’s time. They also collected data on household consumption and production and other relevant characteristics. They found very high discount rates in all three countries and a systematically higher discount rate among the poorest. The lower time-spans and myopic behavior present in poor households could also be understood as rational behavior under a different mind setting. In any case, although it is not even close to be conclusive evidence on the matter, we find that these studies suggest that poor households behave differently than rich households.

III. The model

Open Economy

This section extends Mendoza (1993) seminal paper to allow behavioral biases in the expectations formation mechanism. In this way, the model can account for the three stylized facts that Aguiar and Gopinath find for developing countries.

The economy is small and the representative agent-firm is infinitely lived. Preferences are defined over sequences of consumption and labor using Stationary Cardinal Utility. This generates an endogenous time preference and therefore a unique invariant ergodic distribution of foreign assets under incomplete markets. Without this assumption, under non insurable income shocks and an exogenous and constant interest rate, foreign debt would diverge to infinity.

The preference specification is:

$$\tilde{E}\left[\sum_{t=0}^{\infty} \rho(c_t - N(L_t))u(c_t - N(L_t))\right]$$ (1)

$u(\cdot)$ is the standard utility function and $\rho$ is a strictly increasing, concave and twice continuously differentiable time preference function. Following Mendoza (2010) utility is defined in terms of the excess consumption relative to the disutility of labor, with the latter given by the twice continuously differentiable convex function $N(\cdot)$. This eliminates the wealth effect on labor supply by making the marginal rate of substitution between consumption and labor independent of consumption. The wig over the expectation operator denotes the use of behaviorally determined expectations and not objective probabilities as in the standard case.

Output is defined by constant returns to scale technology $e^{zt} F(k_t, L_t, v_t)$. This is, in order to produce the final tradable good (sold at an internationally determined price) it requires capital, $k_t$, labor, $L_t$ and imported inputs, $v_t$.

Net investment is $x_t = k_{t+1} - k_t$ and there are linear unitary costs $\Phi(x_t/k_t)$. Working capital loans are obtained from foreign lenders at the beginning of each period and repaid at the end.
Lenders charge the world gross real interest rate, \( R_t = R e^{\epsilon_t} \) where \( \epsilon \) is an interest rate shock around mean \( R \). Imported inputs are purchased at an exogenous relative price in terms of the world numeraire, \( p_t = p e^{\gamma} \), where \( p \) is the mean price and \( \gamma \) is a shock to inputs. All shocks follow a first order Markov process.

The period budget constraint is

\[
e_t + i_t = e^{zt} F(k_t, L_t, v_t) - p_t v_t - \phi(R_t - 1)(w_t L_t + p_t v_t) + q^b_t b_{t+1} - b_t
\]

where \( i_t = \delta k_t + (k_{t+1} - k_t)[1 + \psi(\frac{\epsilon_t}{\epsilon_t})] \) is gross investment and \( q^b_t \) is the exogenous price of bonds equal to \( 1/R_t \). The fraction of the cost of imported inputs and labor in advance of sales is represented by \( \phi \) and therefore \( \phi(R_t - 1)(w_t L_t + p_t v_t) \) represents working capital loans. The expression \( q^b_t b_{t+1} - b_t \) is the changes in foreign holdings (including interests).

Rearranging (2) we can obtain the trade balance of this economy

\[
e^{zt} F(k_t, L_t, v_t) - p_t v_t - c_t - i_t = \phi(R_t - 1)(w_t L_t + p_t v_t) + q^b_t b_{t+1} - b_t
\]

In this model, the concept of equilibrium will be slightly different to the one used in Mendoza, because we will use subjective expectations. A behavioral equilibrium in will be defined by functions such that, given subjective expectations about future productivity, households maximize the value function subject to their budget constraint, firms maximize profits and there is consistency between aggregate and individual variables.

**Expectation Formation Mechanisms**

As previously noted, productivity follows

\[
z_t = \rho z_{t-1} + \epsilon_t
\]

Where \( \epsilon \) is white noise. We will assume for computational simplicity, that it can take only two values: \( \epsilon_H, \epsilon_L \) with \( \epsilon_H > \epsilon_L \). Agents will assign a different persistence to the observed shocks of the innovation. There are three different models under which agents will form expectations. All three models have the same structure of Markov processes but will differ in the transition probabilities.

Model \( M_1 \), has the following transition probabilities

\[
\begin{pmatrix}
\pi_L & 1 - \pi_L \\
1 - \pi_L & \pi_L
\end{pmatrix}
\]

Element \( \pi_L = \text{Prob}(\epsilon_t = \epsilon_j | \epsilon_{t-1} = \epsilon_i) \) represents the transition probability from state a state to itself, whereas \( 1 - \pi_L \) represents transitions from one state to a different one.\( 1 - \pi_L = \text{Prob}(\epsilon_t = \epsilon_i | \epsilon_{t-1} = \epsilon_j) \), with \( i \neq j \).

Model \( M_2 \) has the following transition probabilities,
\[
\begin{pmatrix}
\pi_H & 1 - \pi_H \\
1 - \pi_H & \pi_H
\end{pmatrix}
\]

Element \(\pi_H\) represents the same transition probability that \(p_i\) does, that is, from state to a state to itself, whereas \(1 - \pi_H\) represents transitions from one state to a different one.

The key in the difference between the models is that \(\pi_H\) is high and \(\pi_L\) is low. Therefore in \(M_1\) it is more likely that the regime is switching and in \(M_2\) people are expecting the trend to continue. Thus, \(M_1\) generates effects identical to those predicted by conservatism and an agent using this model will react too little to an individual productivity shock. An agent using \(M_2\) to forecast future income will behave as if he is subject to the representativeness heuristic. After a string of positive or negative productivity shocks, the agent will put more weight to \(M_2\) to forecast future earnings, extrapolating past performance too far into the future. The true model, \(M_3\) has all elements equal to .5.

We will restrict the space of models to be \(S_1 = \{M_1, M_2\}\). Agents will only be able to choose from Models one and two. In other words, agents are bound to make mistakes and are not aware of the true model. We also explored the possibility of allowing agents to choose from a space \(S_2 = \{M_1, M_2, M_3\}\). This obviously weakens the effect of the behavioral biases and the macro implications we intend to explore. It also it creates the need of more free parameters, making the results more dependent on them so I do not report the results of this setting. It is worth noting, however, that even if we allow the agent to choose from the true model expectations will not converge to rational expectations in the limit. The cause lies in the fact that nature is constantly shocking the economy and therefore agents can never settle on the correct distribution to form expectations.

Agents will think that the rule governing the transition between models \(M_1\) and \(M_2\) follows

\[
\Lambda = \begin{bmatrix}
1 - \lambda_1 & \lambda_1 \\
\lambda_2 & 1 - \lambda_2
\end{bmatrix}
\]

That is, \(\lambda_1 = \text{Prob}(M_t = M_2 | M_{t-1} = M_1)\) and \(\lambda_2 = \text{Prob}(M_t = M_1 | M_{t-1} = M_2)\). In other words, agents believe the model to switch from \(M_1\) to \(M_2\) with probability \(\lambda_1\). We will assume both \(\lambda_i\) to be high, implying that changes in the regimes are not frequent and that \(\lambda_2 > \lambda_1\), meaning that the agents are more prone to become optimistic than to remain pessimistic, consistent with psychological evidence.

**Bayesian Learning**

Let’s define \(q_t = \text{Pr}(M_t = M_1 | q_{t-1}, \epsilon_{t-1})\). When allowing the agent to choose from the space \(S_1\), bayesian update in the previous framework would dictate that

\[
q_t = \frac{[(1 - \lambda_1)q_{t-1} + \lambda_2(1 - q_t)]\text{Pr}(\epsilon_t | M_t = M_1, \epsilon_{t-1})}{(1 - \lambda_1)q_{t-1} + \lambda_2(1 - q_t)]\text{Pr}(\epsilon_t | M_t = M_1, \epsilon_{t-1}) + [\lambda_1q_{t-1} + (1 - \lambda_2)(1 - q_t)]\text{Pr}(\epsilon_t | M_t = M_2, \epsilon_{t-1})}
\]
Defining \( \psi_1 = Pr(\epsilon_{t+1} = \epsilon_H | \epsilon_t, q_t) \) and \( \psi_2 = Pr(\epsilon_{t+1} = \epsilon_L | \epsilon_t, q_t) \), the expectation on the future productivity shock is

\[
E(z_{t+1}) = \rho z_t + \psi_1 \epsilon_H + \psi_2 \epsilon_L
\]

**Learning through Categories**

In this case, as we mentioned earlier, the information will be classified in discrete number of sets instead of a combination among them as in the case of Bayesian Updating. Therefore, when one model is more likely to be the one behind the observed productivity shocks, the agents will use that model in their expectation formation and will disregard the other. Mathematically,

- \( Pr(M_t = M_1) = q_t > 0.5 \implies M_1 \)
- \( Pr(M_t = M_2) = 1 - q_t > 0.5 \implies M_2 \)

Each time, the agent optimizes “forever” and re-optimizes when the condition is satisfied. Expectations are in some sense “sticky”.

**Solution Algorithm**

The problem presented here cannot be solved with standard algorithms so a brief explanation of the process is in order. Linearization needs the rational expectation equilibrium in order to linearize around that steady state, and the very same process looses information of higher orders. Therefore, linearization methods deteriorate quickly in the presence of large shocks and high risk aversion (Dorofeenko et al, 2005) making it specially important in the case of developing countries.

The simulation is performed using Value Function Iteration. Specifically, we will obtain policy functions given subjective expectations and then perform simulations using the different functions.

The algorithm works as follows: First, the probability that the model behind the observed productivity process is \( M_1, q \in [0, 1] \) will be divided in a grid \( i \) spaces. Given each of the \( q_i \) in the grid, we will compute the policy function using Howards Improvement Algorithm (see, Ljungqvist and Sargent, 2004), obtaining functions \( k_i(k, z) \). Therefore we will have \( i \) policy functions. For the simulation we will compute, for each productivity shock the probability \( q_t \), and use the corresponding \( q_i \), therefore joining the simulations.

The functional forms will be the same as in Mendoza (2003) and the calibration is from Mendoza (2010) using Mexican data.

\[
u(c_t - N(L_t)) = \frac{[c_t - \frac{L_t^\omega}{\omega}]^{1-\sigma} - 1}{1 - \sigma}
\]

with the coefficient of risk aversion, \( \sigma \) and \( \omega \) are greater than 1. The latter parameter determines the elasticity of labor supply given by \( 1/\omega - 1 \).

\[
\rho(c_t - N(L_t)) = \zeta [Ln(1 + c_t - \frac{L_t^\omega}{\omega})]
\]
Where $\zeta < \sigma$ is the semi elasticity of the rate of time preference with respect to the composite good. The restriction for this parameter to be lesser than the risk aversion parameter is required to ensure a unique invariant ergodic distribution of bonds and capital.

\[
e^{zt} F(k_t, L_t, v_t) = Ak_t^\beta L_t^\alpha v_t^\eta
\]

\[
\Phi(x_t/k_t) = \frac{a}{2} \left( \frac{z_t}{k_t} \right)
\]

with $a > 0$.

**Numerical Results**

<table>
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<th>Bayesian</th>
<th>Categories</th>
<th>Mendoza 93</th>
<th>Data</th>
</tr>
</thead>
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<tr>
<td>$\rho_{TB, GDP}$</td>
<td>-0.64</td>
<td>-0.73</td>
<td>0.032/-0.08</td>
<td>-0.58</td>
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<td>$\frac{\sigma_{CI}}{\sigma_{GDP}}$</td>
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<td>1.7</td>
<td>0.8</td>
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</tbody>
</table>

Table 1: Open Economy Model Results: Trade Balance and Consumption. $\rho_{TB, GDP}$ is the correlation of trade balance to output to GDP and $\frac{\sigma_{CI}}{\sigma_{GDP}}$ is consumption to output volatility. Data is the average found in Aguiar and Gopinath for a sample of emerging markets and Mendoza93 is the theoretical result of the baseline model -without behavioral considerations-.

As can be observed from Table 1, the anticyclial behavior of the trade balance is successfully explained by our model as well as the higher consumption to output volatility found by Aguiar and Gopinath (2007). Baseline RBC model predicts a near random walk behavior for the trade balance. In our model, after a string of positive agents expecting a higher income in the future increase consumption today deteriorating the trade balance relatively more. The consumption to output ratio behavior follows the same logic, because this makes consumption more volatile than output. Although, it is worth noting that output ends up being more volatile than in the baseline model as well since increase TFP also increases investment, but it is less relatively volatile. Aguiar and Gopinath’s premise is that emerging markets are characterized by frequent regime switches and therefore model shocks to the growth trend. It is interesting to note that this can happen agents do not internalize the probability of a change in the trend (avoiding the peso problem) or if the event is of zero measure. In our model provide the same logic when explaining the facts but arguing that people are not fully rational when internalizing that probability.

In order to generate a sudden stop we need to define a debt limit for the economy. Let $\tilde{b}^P(z_t, q_t)$ be the debt limit under a pessimistic mental frame. Obviously, the debt limit under the optimistic model would never be reached. This limit will be defined as a proportion of the stream of output at the steady state level of capital discounted at the marginal productivity of steady state capital: $(1 - \alpha) \frac{f(k^*)}{f(k^*) - \delta}$. That is, a proportion of the wealth of the economy (the discounted stream of output at future productivity). The logic behind the use of a proportion of wealth is that consumption cant be lower than a proportion $\alpha$ of output forever, for political economy reasons (not modeled). We assume foreign lenders share the expectations of future wealth.

The literature on sudden stops modeled the capital markets as subject to financial market imperfection and informational frictions. Sudden Stops literature focuses mostly on the transmission mechanisms of a zero probability measure shock, while we generate an endogenous misforecast of
Table 2: Open Economy Model Results: Sudden Stops. Sudden Stops represents the frequency of defaults in 1000 simulations.

future wealth which lead to the agents to take a higher than optimal foreign debt position which turns out to be unsustainable when expectations are reversed. A standard RBC model provides no possibility of a sudden stop because there is no cause for this to happen. Agents (debtors and lenders) perfectly foresight the future and take or give debt in order to smooth consumption across time and states. Debt is an instrument to smooth consumption and is therefore a function of the level of wealth. If wealth forecast changes, the amount of debt taken can be substantially different to the optimal one thereby causing an inability to pay. Our setup can trigger a sudden reversal of expectations because while under an optimistic mental framework a certain level debt can be sustainable, it might not be when optimistic expectations are corrected to the original or the pessimistic model. The level of debt taken during optimistic booms can be high enough as to prompt a default. Overoptimistic economies will take debt expecting a higher future productivity and output, expectations that will be frustrated when these are not realized. Creditors will realize this at the same time that the economy does (since we assumed so) and will stop providing credit. This explanation is, of course, very dependent on the history of productivity shocks and therefore we change the seeds of the simulation and provide the results of 1000 simulations in Table 2. We use $\alpha = .6$, but the numbers are similar for $\alpha = .5$.

Policy Implications

In this section we will present the simplest possible model in order to analyze theoretically the usefulness of fiscal policy in this scenario. The simplification is mostly because of the computational need of a new state variable and in order to isolate the effect we are intending to highlight, namely the effect of countercyclical spending on consumption volatility. The results are consistent with those presented by Heymann and Kawamura (2009): in the presence of misperceived trends anticyclical fiscal policy can be welfare improving.

The economy is closed and the agent supplies labor inelastically and there is only one factor, capital. Agents pay taxes and receive transfers.

Government spending is modeled in a somewhat unusual matter, in order to ensure tractability. Government spending will follow a stable AR(1) process, displaying persistence. This feature will generate optimism in future disposable income when government spending rises. I normalize the interest rate that the government faces to zero. In this way, given the mean reversion that the government expenditure process presents, we ensure that debt will be sustainable and that the government will meet the transversality condition.

The government intertemporal budget constraint is given by
Assuming the transversality condition holds. We will make assumptions below to ensure that this happens. We suppose that the government can take credit to a risk free international rate that we will be set to zero, \( r_t = r^{free} = 0 \). Also, we will suppose that the operating expenses from the government are constant. Transferences, however, can be either positive or negative and the difference will be supplied with the international bonds, \( b_t \). Therefore,

\[
g_t = \tau_t + b_t
\]

in each period.

The agents have to form expectations about government expenditure. They assume it follows

\[
\tau_t = \hat{\tau} + \rho \tau_{t-1} + \nu_t
\]

The innovation \( \nu \) can take two values, \( \nu_H, \nu_L \)

Setting \( \hat{\tau} = 0 \), \( \rho < 1 \) and \( r_t = r^{free} = 0 \) we can ensure that there will be persistence in government spending and the the debt will be sustainable. The first one is self evident since the autocorrelation coefficient is positive, and the second one is a consequence of the mean reversion of the process (since \( \rho < 1 \) is less than one) together with the interest rate set to zero.

The agent solves the following dynamic program

\[
V(k, z, \tau) = \max_{k', \epsilon} \{ u(c) + \beta \tilde{E}_t[V(k', z', \tau')] \}
\]

subject to

\[
y = c + i + (g - \tau)
\]

\[
i = k' - (1 - \delta)k - f(k'/k)
\]

\[
\tau_t = \hat{\tau} + \rho \tau_{t-1} + \epsilon_t
\]

Where (12) represents the resource constraint in the economy and (13) represents the law of motion of capital. \( \tilde{E}_t \) represents subjective expectations, which will be updated based on learning on the space of models. Production is Cobb Douglas, \( y_t = e^{z_t} k_t^\alpha \). The exogenous productivity shock can, for the sake of simplicity, take only two values, high and low. Government spending is represented by \( g_t \) which must be payed using goods from the economic system. This would include operating costs from the government. However, we will allow the government to take debt and pay the operating expenses using goods from abroad so only a part \( g_t - \tau_t \) is used from the goods within the economic system.

Rewriting the feasibility constraint,
\[ e^{z_t} k_t^\alpha = c + k' - (1 - \delta)k + (g - \tau + \rho \tau_{t-1} + \nu_t) \quad (15) \]

In this section agents will form expectations about the joint distribution of \( \tau_t \) and \( z_t \). We will define this variable \( s_t = [z_t, \tau_t] \). This is the shock to disposable income, since a higher productivity increases disposable income as well as a higher transference from the government. Agents will generate expectations about the distribution of \( s_t \) among three joint states of disposable income possibilities: high, low and medium or \( s_H = [z_H, \tau_H] \), \( s_L = [z_L, \tau_L] \) and \( s_M = [z_H, \tau_L] = [z_L, \tau_H] \). Note that the latter expression implies that both shocks to disposable income are exchangeable for the agent.

\[
\begin{pmatrix}
\pi_1 \\ 1 - \pi_1 \\ 1 - \pi_1 \\ 1 - \pi_1 \\ \pi_1 \\ 1 - \pi_1 \\ 1 - \pi_1 \\ 1 - \pi_1 \\
\end{pmatrix}
\]

The key here is that \( \pi_1 = \text{Prob}(s_t = [z_i, \tau_i]|s_{t-1} = [z_i, \tau_i]) \) for \( i = H, L, M \). In other words, the diagonal represents the probability of repeating the same state. As in the previous section, an agent can only choose from two models, \( S_1 = \{M_1, M_2\} \) where \( M_1 \) will be a reversionist model (low \( \pi_1 \)) and \( M_2 \) will be a trend following model (high \( \pi_1 \)). Agents will learn from the two models bayesianly as explained before using both Category Learning and pure Bayesian Learning.

Anticyclical fiscal policy will take an unusual form in this paper. We will assume that government spending is generated through 10, but with a lower persistence (a lower \( \rho \)). This clearly will generate an average countercyclical behavior to the actions by the households. Therefore, agents know how the agent behaves but misperceive the persistence in general.

**Numerical Results**

We will use the very standard log form, \( u(c) = \log(c_t) \) and the Cobb-Douglas function for production for the parametrization of the problem.

The problem presented here cannot be solved with standard algorithms. The process is the same as in the closed economy case; we will obtain policy functions given subjective expectations and then perform simulations using the different functions. Instead of focusing on the single shock, \( z_t \), the joint distribution of \( s_t \) is used.

<table>
<thead>
<tr>
<th>( \sigma_c )</th>
<th>Bayesian</th>
<th>Categories</th>
<th>Standard RBC</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Fiscal policy</td>
<td>2.8</td>
<td>3.1</td>
<td>2.2</td>
</tr>
<tr>
<td>Simple Rule</td>
<td>2.4</td>
<td>2.7</td>
<td>–</td>
</tr>
</tbody>
</table>

Table 3: Fiscal Policy Model Results . \( \sigma_c \) is consumption volatility .

The simple fiscal policy case we are presenting here successfully lowers consumption volatility, and given a risk averse agent it increases welfare. In the case of an economic downturn, a countercyclical fiscal policy not only boosts aggregate demand today, but it also restores confidence. The government can alter disposable income by lowering taxes or raising transfers, therefore
boosting actual consumption and restoring confidence over future disposable income boosting investment. Even more, another conclusion that arises from the model is that fiscal policy is more effective if applied quickly, at the beginning of the downward trend, because otherwise the agents will enter in a pessimist mental model and a more sustained stimulus will be necessary to restore confidence. In the case of an optimistic mind setting, countercyclical policy corrects expectations on future disposable income and leads to the right direction.

The desirability of an anticyclical fiscal policy when the economy has biased expectations has already been analyzed by Heymann and Kawamura (2009). Our model provides the same policy prescription in an infinite horizon model with endogenous expectations.

IV. Conclusions and Further Research

We presented a simple model where there is an intrinsic instability due to the agent’s passions and fears, departing from the standard rational expectations assumption. We believe this represents to a certain degree Keynes’ Animal Spirits in a DSGE framework.

Jaimovich and Rebelo (2007) also model behavioral biases but they analyze static biases. Agents are either optimistic or overconfident. In our model we generate a dynamic in agent’s beliefs generating a trend-following sort of behavior, a in Heymann and Sanguinetti (1998) and Heymann et al (2001).

The evidence supporting this assumption is exclusively found in individual’s decision makings and thus not applicable to macroeconomics a priori. However, the literature is acknowledging that international organisms and markets expectations can have biased expectations towards better outcomes after a period of good news, as Figure 1 clearly shows.

Even when the evidence supporting the assumption is weak and suggestive at best, the inclusion of these behavioral biases into a DSGE framework can account for three stylized facts that standard models cannot account for, namely the countercyclical behavior or trade balances, the high consumption to output volatility and the presence of sudden stops. The trade balance is countercyclical and the consumption to output is more volatile in our model because optimism leads to a misperception about future income and therefore to a higher consumption out of current income. For the high consumption volatility we believe that an incomplete markets explanation is a potentially more important explanation, but biases on future income can certainly contribute. Aguiar and Gopinath (2007) explain these using non stationary shocks to growth trend. It is worth noting that the explanations are the same in the underlying logic, but in their model agents perfectly forecast the future and are subject to shocks while in our’s, agents do not know the actual probability distribution and interpret the observed shocks, thereby making the misforecast endogenous. This opens up the possibility of some welfare improving government action.

The desirability of an anticyclical fiscal policy when the economy has biased expectations has already been analyzed by Heymann and Kawamura (2009). Our model provides the same policy prescription in an infinite horizon model with endogenous expectations. However, their model can...
answer a wider set of questions given that they have a tradables and a non tradables sector and heterogeneous agents. It is in our agenda to generalize the present model in order to analyze those issues.

As for future research, although the results seem to be robust to similar values of the expectation formation parameters, the first thing in our agenda is to work on an estimated version of this model.

References


Appendix: Calibration