Achieving two policy targets with one policy instrument: heterogeneous expectations, countercyclical fiscal policy, and macroeconomic stabilization at the effective lower bound

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We explore the short-term macrodynamics of stabilization policy at the effective lower bound (ELB) of the nominal interest rate, in an environment characterized by heterogenous and endogenously time-varying private-sector output and inflation expectations driven by evolutionary dynamics. We show that at the ELB, fiscal policy conducted in accordance with a well-specified policy rule is particularly effective for purposes of macroeconomic stabilization. This is because fiscal interventions have both a direct effect on output and inflation (via aggregate demand formation) and an indirect effect on these same target variables, via the management of heterogenous and evolving expectations. As a result of the two channels through which it operates, and seemingly despite the logic of the Tinbergen (targets-instruments) principle, fiscal policy is thus revealed as a single policy instrument capable of achieving two policy goals.

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JEL Codes: E12, E52, E58, E62, E63, E71.

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1. Introduction

During the past two decades, confronting the zero lower bound (ZLB) for the nominal interest rate has been one of the most important challenges for monetary policy in the U.S. and various other developed economies. A key issue at stake concerns the extent to which, and how, the ZLB represents a genuine constraint on attainable targets for inflation (and possibly real output) as stable equilibrium outcomes. As theoretically articulated and empirically confirmed, the ZLB represents an important constraint on what *conventional* monetary stabilization policy can achieve, forcing monetary policy to rely on *unconventional* monetary policy tools. In principle, further monetary policy accommodation at the ZLB can be achieved by means of policy tools such as forward guidance (which provides market participants with information about the intentions of monetary policy makers for the future path of the nominal interest rate) and quantitative easing (which involves large-scale purchases of public and in some cases private assets). It is often argued that these unconventional monetary policy tools were effective, to varying degrees and in different ways, in the wake of the 2008 financial crisis.[1]

The obstacles and challenges to stabilization policy posed by the ZLB have been extensively explored in the mainstream theoretical and empirical literature on monetary policy making.[2] Indeed, similar challenges are understood to arise if the economy operates *sufficiently near* to the ZLB – hence the notion of an *effective* lower bound (ELB) to the nominal interest rate, to which we consistently refer hereafter. However, the connection between policy-making at the ELB and endogenously time-varying heterogeneity of inflation and output expectations – for which there is indeed considerable empirical and experimental evidence – has been absent from this literature. Neither has this connection been explored

[1] See, for example, Gambacorta, Hofmann and Peersman (2014), who provide evidence from eight advanced economies, Kuttner (2018) for evidence from the United States, and Dell'Ariccia, Rabanal and Sandri (2018) for evidence from the Euro Area, Japan and the United Kingdom.

[2] For recent examples, see the "Symposium on Monetary Policy at the Effective Lower Bound" featured in the Fall 2018 issue of the *Brooking Papers on Economic Activity*, and the "Session on Monetary Policy Frameworks and the Zero Lower Bound" featured in the 2019 issue of the *American Economic Association Papers & Proceedings*.

in the heterodox macroeconomic literature: although heterogeneous inflation and output expectations formation are considered in Lima, Setterfield and Silveira (2014, 2020), there is no exploration of the potential role of fiscal policy at the ELB. This neglect on the part of the heterodox macroeconomic literature is surprising given the weight attached by Keynes himself to the importance of expectations as a key driver of economic behavior, and Keynes's consideration of what can be done to stabilize the economy when it falls into a 'liquidity trap' – that is, when the nominal interest rate is reduced to a level below which it cannot fall further in response to monetary policy.[3]

The effective management of inflation and output expectations is evidently key to successful stabilization policy at all times, not just in the relatively unusual (from a longer-term perspective) circumstances imposed by reaching the ELB. However, when the latter is reached, and thus conventional monetary policy based on the further lowering of the nominal interest rate becomes infeasible, an issue that arises is whether fiscal policy can substitute for *conventional* monetary policy as a device for macroeconomic management, especially (but not only) when *unconventional* monetary policy tools such as forward guidance or quantitative easing are unavailable. Consider, for example, an explicit fiscal policy rule, according to which aggregate-demand-creating (and thus expansionary) fiscal policy is adopted more (less) intensively when output (inflation) is below (above) its official target. We show that with heterogenous and endogenously time-varying inflation and output expectations, fiscal policy contributes to the achievement of both inflation and output targets by operating directly as a policy instrument *and* indirectly, as an instrument for managing output and inflation expectations. While management of

[3] As Keynes stated in chapter 15 of the *General Theory* on the psychological and business incentives to liquidity: "There is the possibility…that, after the rate of interest has fallen to a certain level, liquidity-preference may become virtually absolute in the sense that almost everyone prefers cash to holding a debt which yields so low a rate of interest. In this event the monetary authority would have lost effective control over the rate of interest. But whilst this limiting case might become practically important in future, I know of no example of it hitherto." (1936, p.207). In fact, in modern parlance, the situation envisioned by Keynes seems closer to a (strictly positive) effective lower bound rather than a zero lower bound. In any case, the future in which Keynes supposed that such a limiting situation might become practically important has arrived.

expectations is a central feature of monetary policy making discussion, at the ELB fiscal policy may be the only conventional instrument capable of such management. Moreover, fiscal policy is rendered surprisingly effective in this management role as long as there is endogenously time-varying disagreement among private decision makers, whose expectation formation is influenced by public-sector policy targets acting as 'anchors'. Specifically, our analytical results demonstrate that at the ELB, fiscal policy can be used to ensure that the dynamics of heterogeneous inflation and output expectations are not only benign, but actively contribute to the achievement of two explicit policy targets (inflation and output). *Prima facie* this analytical result is surprising, in that it would appear to violate the Tinbergen (1952) principle according to which there needs to be as many linearly-independent policy instruments as there are linearly-independent policy goals to be achieved. In our model, however, the evolutionarily satisficing dynamic driving heterogeneous private-sector inflation and output expectations formation acts as a 'surrogate' policy instrument in its key role as an adjusting variable, so that the Tinbergen principle is in this sense satisfied.

The remainder of the paper is organized as follows. Section 1 outlines the baseline macrodynamics on which our analysis is based, while in Section 2 we describe a complementary micro-structure based on noisy satisficing evolutionary dynamics in the spirit of the evolutionary contributions of Simon (1955, 1956) on bounded rationality. Section 3 analyses the interaction between our micro- and macro-dynamics with a particular focus on the capacity of fiscal policy to stabilize the economy, despite its being a single instrument operating on two policy targets (output and inflation). Section 4 discusses the significance and policy implications of our results and finally, section 5 concludes.

2. Macrodynamics: a benchmark model

We begin with the following benchmark dynamic macroeconomic model:

(1) $$y = y_0 - \delta r^e + \lambda g + \gamma y^e ,$$

(2) $$p = \beta + \varphi p^e + \alpha y ,$$

(3) $$\dot{g} = -\mu(y - y^T) - \psi(p - p^T) ,$$

(4) $$r^e = \bar{i} - p^e ,$$

(5) $$\dot{p}^e = -(1-k)(p - p^T) ,$$

(6) $$\dot{y}^e = -(1-k)(y - y^T) ,$$

where y is the level of real output, y_0 represents non-interest sensitive components of aggregate spending, r^e is the real interest rate, g is a fiscal policy variable contributing to aggregate spending,[4] y^e denotes the expected real output, y^T denotes the policy authorities' target level of real output and p^T their target rate of inflation, both exogenously given, p and p^e are the actual and expected rates of inflation, respectively, and $\bar{i}$ is the fixed level of the nominal interest rate, capturing the idea that the economy is at or close enough to the zero lower bound – in other words, that it is at the *effective* lower bound (ELB). As usual, a dot over a variable denotes its rate of change (i.e., $\dot{x} = dx/dt$). Finally, β denotes an exogenous component in inflation dynamics and the other Greek letters represent strictly positive parameters.

Equation (1) is simply an aggregate demand schedule also featuring a positive impact of expected output, which captures the idea that current spending and hence output varies positively with expected

[4] Following Setterfield (2007), the fiscal policy variable g can be thought of as representing, for example, the size of the public-sector borrowing requirement (PSBR) in real terms.

future output (and hence income). Equation (2) is an expectations-augmented Phillips curve, in which it is reasonable to assume that $\varphi < 1$, which is consistent with the notion that workers lack the bargaining power to fully index expected inflation into nominal wage growth. Equation (3) describes the conduct of fiscal policy in terms of a "pseudo Taylor rule" (Setterfield, 2007), with the public-sector borrowing requirement (PSBR) behaving in a countercyclical manner by falling (rising) whenever either output or inflation is above (below) its official target. Equation (4) is a Fisher-like relationship, relating the expected real interest rate to the nominal rate of interest and the expected rate of inflation.[5] Observe that the ELB means that there is a lower bound on the (expected) *real* interest rate of $\bar{i} - p^e$. In addition to the expected rate of inflation, the precise value of this lower bound will, of course, depend on the precise value of the ELB, which may be slightly greater than zero, equal to zero or (following recent experience in Sweden, Denmark, Japan, Switzerland, and the euro area) even slightly lower than zero (see, e.g., Agarwal and Kimball, 2019, on negative nominal interest rates). What is most relevant for stabilization policy in the first instance, however, is not so much the precise value of the ELB, denoted by $\bar{i}$ in equation (4), but rather that the nominal interest rate cannot be lowered further, so that $di/dt = 0$.[6] Therefore, we abstract from the possibility of a negative interest rate to focus more sharply on the implications for stabilization policy of a nominal interest rate the value of which cannot be further reduced even if it is still but only slightly greater than zero. The reader will notice the upward (as well as downward) rigidity of the nominal interest rate that is implied by this assumed fixity of the nominal rate. Upward rigidity of the nominal rate can be plausibly justified by the assumption that the central bank operates on a non-Neo-Fisherian view

[5] Mainstream economists typically believe that, in the long run, the real interest rate is independent of nominal factors, which means that a long-run increase in the nominal interest rate translates into a one-for-one increase in inflation. Since we do not (and do not need to) endorse this strict interpretation of the Fisher relationship, we simply refer to (4) as a "Fisher-like" relationship.

[6] In fact the precise value of the ELB on the nominal interest rate might matter in the event that it could become strictly negative. We abstract from such a possibility to avoid overloading the model with further structure, since a strictly negative nominal interest rate raises additional conceptual and analytical issues.

(NNFV) of the economy. The so-called Neo-Fisherian view (NFV – see, e.g., Williamson, 2016, and Garín, Laster and Sims, 2018) holds that the monetary authority should *raise* (rather than lower) interest rates in order to stimulate the economy. The hypothesis behind the NFV is that an increase in the nominal interest rate can raise inflation expectations (via the cost channel of monetary policy, for example – see Lima and Setterfield, 2014) and so reduce the real rate of interest in the Fisher equation. The NNFV rejects the NFV and instead holds to the more orthodox view that a nominal rate cut is required to stimulate the economy. A central bank operating on a NNFV of the economy will not raise the nominal interest rate at the ELB precisely because of the macroeconomic circumstances (a depressed economy) that have brought it to the ELB in the first place. In short, the ELB renders the nominal rate rigid downwards, while the combination of macroeconomic circumstances and a NNFV of the economy render it effectively (if not literally) rigid upwards. The nominal interest rate at the ELB can therefore be regarded as fixed. The recent (and not entirely successful) experience of some countries with lowering the nominal interest rate from slightly above to slightly below zero is suggestive that a non-zero ELB is likely to be endogenous, state-dependent, and time-varying rather than exogeneously fixed. We abstract from this possibility, however, in order to sharpen focus on the implications for stabilization policy of a given ELB. Nevertheless, and as elaborated below, even with a fixed ELB on the *nominal* interest rate the effective lower bound on the (expected and actual) *real* interest rate, which is considerably more relevant for the macrodynamics of the economy, is endogenously time-varying.

Equations (5) and (6) are motivated by the considerable empirical evidence from survey data and laboratory experiments suggesting that both inflation and output expectations are persistently heterogeneous and formed (predominantly) through boundedly rational mechanisms (see, e.g., Hommes, 2013 and Coibion, Gorodnichenko and Kumar, 2018). They posit that, rather than interacting with homogeneous decision makers who base expectations on a single salient and time-invariant 'true model', policy makers confront a private sector in which decision making is based on different subjective models of the economy and in which the basis for opinions about the future is evolving.[7] In both equations, $k \in [0,1] \subset \mathbb{R}$ denotes the proportion of incredulous agents who form expectations in accordance with current inflation and output, whereas $1-k$ denotes the proportion of credulous agents whose expectations are anchored to the official inflation and output targets. Ultimately, the proportion $1-k$ can be thought of as measuring the credibility of the policy authorities' commitment to achieve the policy targets p^T and y^T. Note that equations (5) and (6) treat the credibility of policy making as homogeneous: it is as if there is only one policy maker (or else perfect coordination between the monetary and fiscal authorities), so that the private sector's assessment of the credibility of both monetary and fiscal policy making is identical. In principle, the credibility associated with the pursuit of p^T and y^T could differ with the level of trust invested in different (fiscal and monetary) authorities. We abstract from this possibility in this paper, leaving its further contemplation to future research.

As in Lima, Setterfield and Silveira (2014), equation (5) is formally derived as follows. The rate of change of expected inflation is a weighted average of the rate of change of expected inflation by incredulous agents ($\dot{p}_i^e$) and the rate of change of expected inflation by credulous ($\dot{p}_c^e$) agents: $\dot{p}^e = k\,\dot{p}_i^e + (1-k)\,\dot{p}_c^e$. As credulous agents expect the convergence of current inflation to the policy target, p^T, in the relevant future for such an expectation formation, while incredulous agents expect inflation to remain unchanged, it follows that $\dot{p}_c^e = p^T - p$ and $\dot{p}_i^e = 0$. Hence, substituting these expressions for $\dot{p}_c^e$ and $\dot{p}_i^e$ into the expression for $\dot{p}^e$ stated above yields equation (5). It follows that the rate of change of

[7] This thinking is increasingly prevalent in macroeconomic models from a variety of theoretical traditions. See, for example, Lima, Setterfield and Silveira (2014, 2020), De Grauwe and Ji (2017), Laidler (2017), Woodford and Xie (2019), King and Lu (2021), and Saratchand and Datta (2021).

expect inflation depends on both the deviation of inflation from its official target and the frequency distribution of strategies to form inflation and output expectations in the private sector. When the inflation gap given by $p - p^T$ is strictly positive (negative) and the proportion of credulous agents is strictly positive, the rate of change of expected inflation is negative (positive), with the result that the level of expected inflation is falling (rising), changing to an extent that varies positively with the proportion of credulous agents.[8]

Therefore, as the ELB means that there is a lower bound on the (expected) *real* interest rate of $\bar{i} - p^e$ in equation (4), it follows from equation (5) that the rate of change of such lower bound, which is given by $-\dot{p}^e = (1-k)(p - p^T)$, depends on the deviation of inflation from its official target and the frequency distribution of strategies to form inflation *and* output expectations in the private sector (recall that $\bar{i}$ is assumed to be constant at its ELB). Interestingly, how a change in the proportion of credulous agents whose expectations are anchored to the official inflation and output targets, $1-k$, will affect the (hence evolutionarily time-varying) lower bound on the (expected) *real* interest rate of $\bar{i} - p^e$ depends on whether the inflation gap given by $p - p^T$ is positive or negative. More precisely, when the inflation gap given by $p - p^T$ is strictly positive (negative), and the proportion of credulous agents is strictly positive, the lower bound on the expected *real* interest rate will be rising (falling), and will be so changing to an extent that varies positively with the proportion of credulous agents. Therefore, when the proportion of credulous agents is strictly positive and the inflation gap given by $p - p^T$ is strictly positive (negative), the constraint on output expansion represented by the ELB on the (expected) *real* interest rate will become

[8] Note that in our model, $\dot{p}^e$ depends strictly on the *difference* $p - p^T$. According to Coibion et al. (2020), attention to inflation is asymmetric, varying directly with the *level* of p. This might, in principle, modify the reaction of $\dot{p}^e$ to a difference $p - p^T$ of any given size. We abstract from this possibility here for the sake of simplicity.

the more relaxed (tightened), the higher the proportion of credulous agents. Meanwhile, given that incredulous agents expect inflation to remain unchanged, $\dot{p}_i^e = 0$, they can be interpreted as ultimately expecting (even if not consciously) that the ELB on the (expected) *real* interest rate will remain unchanged.

Analogously, equation (6) is formally derived as follows. The rate of change of expected output is a weighted average of the rate of change of expected output by incredulous agents ($\dot{y}_i^e$) and the rate of change of expected output by credulous ($\dot{y}_c^e$) agents: $\dot{y}^e = k\,\dot{y}_i^e + (1-k)\dot{y}_c^e$. As credulous agents expect the convergence of current output to the policy target, y^T, in the relevant future about which such an expectation is formed, while incredulous agents expect output to remain unchanged, it follows that $\dot{y}_c^e = y^T - y$ and $\dot{y}_i^e = 0$. Consequently, substituting these expressions for $\dot{y}_c^e$ and $\dot{y}_i^e$ into the expression for $\dot{y}^e$ stated above yields equation (6). It follows that the rate of change of expect output depends on both the deviation of output from its official target and the frequency distribution of strategies to form inflation and output expectations in the private sector. When the output gap given by $y - y^T$ is strictly positive (negative) and the proportion of credulous agents is strictly positive, the rate of change of expect output is negative (positive), so that the level of expect output is falling (rising), and will be changing in such a suitable way policy-wise to an extent that varies positively with the proportion of credulous agents.

Note that the incredulity exhibited by our incredulous agents is, in fact, a ‘soft’ incredulity, in that it expresses incredulity only about the likely convergence of inflation and output to their official targets. When an official policy target is achieved, incredulous agents expect the value of the respective variable to then remain constant. ‘Hard’ incredulity could be characterized as agents expecting any deviation of inflation or output from their respective official target values to become self-reinforcing rather than self-correcting, so that $\dot{p}_i^e = p - p^T$ or $\dot{y}_i^e = y - y^T$, respectively. But even in this case incredulous agents would still expect the value of inflation or output to remain constant once their official target values have been achieved. As such, a still harder incredulity verging on extreme pessimism might be associated with agents who both: expect a deviation of inflation or output from their respective targets to be self-reinforcing; *and* also expect the inflation of output to keep changing even following the achievement of an official target value. We leave exploration of these behaviours to further research.

The rationale for this benchmark model is as follows. The "true model" has a Post-Keynesian structure (codified in the existence of a long run relationship between p and y evident in the Phillips curve in equation (2) and the conventional method of expectations formation in equations (5) and (6)).[9] As the economy is at the ELB, however, policy makers possess only one instrument (g) to pursue two targets (y^T and p^T in the pseudo Taylor rule in equation (3)). The ELB thus seemingly presents the public sector with a Tinbergen (1952) policy-making problem: there are too few (linearly independent) policy instruments available to pursue too many (linearly independent) policy targets. It will become clear in what follows, however, that this Tinbergen problem may be more apparent than real. In fact, thanks to the formulation and revision of expectations in the private sector that are anchored to some degree by the policy targets formulated in the public sector, the frequency distribution of strategies to form inflation and output expectations in the private sector becomes another adjusting variable (and in some sense an indirect or quasi-policy instrument) alongside with the fiscal policy instrument.

By combining equations (1)-(6), we get the dynamic system that solves for the macroeconomic equilibrium for a given degree of credulity of the private sector in the policy authorities' commitment to

[9] As will be made clear in what follows, the structure of the Phillips curve so-described does not affect our central policy result – that it is possible to achieve two targets with one (fiscal) policy instrument when operating at the ELB in the presence of heterogeneous, evolutionarily time-varying expectations.

achieve both targets (p^T, y^T) – i.e., for a given proportion of credulous agents, $1-k$. First, note that from equation (1):

(7) $$\dot{y} = -\delta \dot{r}^e + \lambda \dot{g} + \gamma \dot{y}^e,$$

which, using equations (3)-(6), can be written as:

(8) $$\dot{y} = -a(y - y^T) - b(p - p^T),$$

where $a \equiv \lambda\mu + \gamma(1-k) > 0$ and $b \equiv \delta(1-k) + \lambda\psi > 0$ for any $k \in [0,1] \subset \mathbb{R}$, given that all parametric constants are strictly positive by assumption.

Similarly, equation (2) yields:

(9) $$\dot{p} = \varphi \dot{p}^e + \alpha \dot{y}.$$

Substituting equations (5) and (8) in equation (9), we arrive at:

(10) $$\dot{p} = -\alpha a(y - y^T) - c(p - p^T),$$

where $c \equiv (\varphi + \alpha\delta)(1-k) + \alpha\lambda\psi > 0$ for any $k \in [0,1] \subset \mathbb{R}$, given that all parametric constants are strictly positive by assumption.

Therefore, for a given vector of structural and policy parameters represented by $(\alpha, \beta, \gamma, \delta, \lambda, \mu, \varphi, \psi, y_0, \bar{i}, p^T, y^T)$, the state transition of output and inflation depends not only on the macroeconomic state (y, p) itself, but also on the frequency distribution of credulity in the policy effectiveness across private agents $(k, 1-k)$.

3. Microdynamics: noisy satisficing evolutionary dynamics

Let us now describe a satisficing evolutionary dynamics which yields the law of motion of the degree of credulity of the private sector in the policy authorities' commitment (and capacity) to achieve both targets (p^T, y^T) in the relevant future for expectations formation – i.e., the proportion of credulous agents, $1-k$. As noted earlier, this proportion can be thought of as measuring the credibility of the policy authorities' commitment (and capacity) to achieve p^T and y^T. Here, we allow $1-k$ to vary endogenously over time in the spirit of Simon (1955, 1956). According to Simon, reality is complicated relative to the information collecting and processing and decision-making capacities of the individual, whether he is a private or public individual. Denied the ability to optimize based on perfect knowledge of the "true model" describing reality, private and public decision-makers alike must instead "muddle through" using boundedly rational heuristics and satisficing criteria as the bases for their expectations and attendant decision making. In this context, choice is inevitably seen as a process of meeting an acceptability threshold rather than selecting the best of all existing alternatives. Experimental evidence on satisficing choice behavior as defined by Simon (1955) is offered in Caplin, Dean and Martin (2011) and Hey, Permana and Rochanahastin (2017).[10]

Consider, then, an agent j who takes the gap between current inflation and the inflation target, $p-p^T$, and the gap between current output and the output target, $y-y^T$, and then compares what we dub the "*policy (in)effectiveness indicator*", $(p-p^T)^2+(y-y^T)^2$, with the policy (in)effectiveness indicator he considers acceptable, $(p^j-p^T)^2+(y^j-y^T)^2$. If the observed indicator is smaller than or equal to the acceptable indicator, agent j does not consider changing his strategy for forming inflation and output expectations. Otherwise agent j becomes a strategy reviser.

[10] The satisficing choice model in Simon (1955) is axiomatized, for example, in Papi (2012) and Kovach and Ülkü (2020). The former uses a deterministic specification, while the latter features a stochastic acceptability threshold.

The level of the "*policy (in)effectiveness indicator*" that is acceptable to an agent depends, inter alia, on idiosyncratic features which are exogenously determined. We therefore assume that acceptable indicators are randomly and independently determined across agents and over time. More precisely, we assume that the acceptable level of policy (in)effectiveness, $(p^j - p^T)^2 + (y^j - y^T)^2$, is a random variable with cumulative distribution function $F : \mathbb{R}_+ \to [0,1] \subset \mathbb{R}$ which is continuously differentiable. Therefore, the probability of randomly choosing a given agent j who considers the current observed policy (in)effectiveness indicator $(p - p^T)^2 + (y - y^T)^2$ as unacceptable is given by:

(11) $$\Pr\left((p^j - p^T)^2 + (y^j - y^T)^2 < (p - p^T)^2 + (y - y^T)\right) = F\left((p - p^T)^2 + (y - y^T)^2\right).$$

Note that, in particular, if the economy achieves both targets (p^T, y^T), we have $F(0) = 0$, so that the measure of agents who consider that the current policy making is not acceptably effective is null.

Meanwhile, the probability that a randomly drawn agent j will consider that the currently observed policy (in)effectiveness indicator is acceptable is simply:

(12) $$\Pr\left((p^j - p^T)^2 + (y^j - y^T)^2 \geq (p - p^T)^2 + (y - y^T)\right) = 1 - F\left((p - p^T)^2 + (y - y^T)^2\right).$$

The measure of credulous agents who become incredulous is then given by:

(13) $$(1-k)F\left((p - p^T)^2 + (y - y^T)^2\right).$$

Analogously, the measure of incredulous agents who becomes credulous is represented by:

(14) $$k\left[1 - F\left((p - p^T)^2 + (y - y^T)^2\right)\right].$$

Hence subtracting equation (14) from equation (13) yields the following satisficing evolutionary dynamics:

(15) $$\dot{k} = (1-k)F\left((p-p^T)^2 + (y-y^T)^2\right) - k\left[1 - F\left((p-p^T)^2 + (y-y^T)^2\right)\right].$$

Next, we consider the reasonable possibility that the satisficing evolutionary dynamics in equation (15) operate in the presence of a noise term, analogous to mutation in natural environments. In a biological setting, mutation is interpreted literally as comprising random changes in genetic codes. In economic settings, as interpreted in Samuelson (1997, Ch. 7), mutation describes a situation in which a decision maker refrains from comparing payoffs and switches strategy at random. Hence the present specification features mutation as exogenous noise in the satisficing evolutionary protocol, leading a certain proportion of agents to choose an inflation and output foresight strategy at random. This disturbance component is meant to capture the effect of (for instance) exogenous institutional factors, such as changes of administration in the fiscal and monetary authorities, or changes in the policy-making framework other than an abandonment of the inflation and output targeting regime (or the expectation thereof by private agents). Alternatively, and following Kandori, Mailath and Rob (1993), random choice behavior can be associated with: an agent exiting the economy with some (fixed) probability, who is then replaced with a new agent who knows nothing about (or is still not sufficiently experienced in) the relevant decision-making process; and/or agents who, for idiosyncratic reasons (from whose determination we abstract), “experiment” once in a while, with exogenously fixed probability.

Drawing on the specification suggested in Gale, Binmore and Samuelson (1995), mutation can be straightforwardly incorporated into the satisficing evolutionary dynamics in equation (15) as follows. Let $\varepsilon \in (0,1) \subset \mathbb{R}$ be the measure of mutant agents that choose an inflation and output foresight strategy in a given revision period independently of the respective payoffs. Therefore, there are $\varepsilon(1-k)$ credulous agents and εk incredulous agents behaving as mutants.

Although mutant agents choose an inflation and output foresight strategy in a given revision period independently of the respective payoffs, an *incredulity bias* can reasonably arise as the ELB is approached from a strictly positive level of the nominal interest rate. In other words, for a given value of the policy (in)effectiveness indicator, credulous (incredulous) mutants may become less credulous (more incredulous) as the ELB is approached, changing their foresight strategy with higher (lower) probability, as they may arguably come to think that the achievement of a given inflation and/or output target becomes more difficult as the ELB is approached. A possible way to capture this enhanced skepticism about the central bank's capacity to achieve its targets, which should manifest (given the payoff differential and the mutation rate) in an increased proportion of incredulous agents as the economy approaches the ELB zone from above, is to make the likelihood that a mutant switches strategy endogenous to the value of the nominal interest rate. More precisely, and recalling that we abstract from the possibility of a negative nominal interest rate, if we assume that the fraction of credulous mutants who switch strategy is given by $1/(1+i)$, the number of credulous mutants who become incredulous is given by $\varepsilon(1-k)/(1+i)$, so that as i goes to zero eventually all credulous mutants become incredulous. Analogously, when the fraction of incredulous mutants who switch strategy is given by $i/(1+i)$, which is decreasing with respect to i, the measure of incredulous mutants who become credulous is given by $\varepsilon ki/(1+i)$, so that as i goes to zero none of the incredulous mutants becomes credulous. For a given nominal interest rate $\bar{i}$, the net flow of mutant agents becoming incredulous agents at the ELB in a given revision period is then the following:

(16) $$\varepsilon(1-k)\left(\frac{1}{1+\bar{i}}\right)-\varepsilon k\left(\frac{\bar{i}}{1+\bar{i}}\right)=\varepsilon\left(\frac{1}{1+\bar{i}}-k\right).$$

Following Gale, Binmore and Samuelson (1995), this noise can be simply added to the evolutionary mechanism (17) to yield the following *noisy satisficing evolutionary dynamics*:

(17) $$\dot{k} = (1-\varepsilon)\left\{(1-k)F\left((p-p^T)^2+(y-y^T)^2\right)-k\left[1-F\left((p-p^T)^2+(y-y^T)^2\right)\right]\right\}+\varepsilon\left(\frac{1}{1+\bar{i}}-k\right).$$

4. The coevolution between macro- and micro-dynamics

The state transition of the economy is determined by the system composed of equations (8), (10), and (17), the state space of which is represented by $\Theta = \left\{(y,p,k)\in\mathbb{R}^3_+ : 0 \le k \le 1\right\}$. Considering the subsystem composed of equations (8) and (10), we have $\dot{y}=0$ and $\dot{p}=0$ for a given k if, and only if, the following condition is satisfied:

(18) $$\begin{bmatrix} -a & -b \\ -\alpha a & -c \end{bmatrix}\begin{bmatrix} y-y^T \\ p-p^T \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \end{bmatrix}.$$

Since $a \equiv \lambda\mu + \gamma(1-k) > 0$ for all $k \in [0,1] \subset \mathbb{R}$ and $c - \alpha b = \varphi(1-k) > 0$ for all $k \in [0,1) \subset \mathbb{R}$, it follows that $\begin{vmatrix} -a & -b \\ -\alpha a & -c \end{vmatrix} = a(c-\alpha b) > 0$ for all $k \in [0,1) \subset \mathbb{R}$. Therefore, the homogeneous linear system in (18) has a unique solution for any $k \in [0,1) \subset \mathbb{R}$, given by $y - y^T = p - p^T = 0$, which is equivalent to $y = y^T$ and $p = p^T$.

Given that $F(0) = 0$ when $p = p^T$ and $y = y^T$, setting $\dot{k} = 0$ in the noisy satisficing evolutionary dynamics in equation (17) yields:

(19) $$-(1-\varepsilon)k + \varepsilon\left(\frac{1}{1+\bar{i}} - k\right) = 0,$$

the solution to which is given by:

(20) $$k = \frac{\varepsilon}{1+\bar{i}} \equiv k^*.$$

Note that $\varepsilon \in (0,1) \subset \mathbb{R}$ and $\bar{i} \in \mathbb{R}_+$ ensures that $k^* \in (0,1) \subset \mathbb{R}$, which is a polymorphic equilibrium characterized by the coexistence of credulous and incredulous agents. Although the strategies deployed to form inflation and output expectations are different across types of agents, they nonetheless yield the same prediction of such variables in the equilibrium configuration, which is characterized by the achievement of the policy targets for inflation and output. Essentially, while credulous agents are always credulous, incredulous agents practice the 'incredulity of Saint Thomas': unless they see that the policy targets have been achieved, they do not believe in the prospect of their achievement.[11]

Thus, the (unique) equilibrium configuration of the dynamic system represented by equations (8), (10), and (17) is given by $\left(y^T, p^T, k^*\right)$. In this equilibrium, it follows from equation (20) that the proportion $k \in (0,1) \subset \mathbb{R}$ of incredulous agents whose expectations are not anchored to the official inflation and output targets varies positively (negatively) with the mutation rate (effective lower bound of the nominal interest rate). Intuitively, the higher the effective lower bound, the lower the proportion of incredulous agents in the equilibrium with achievement of the official inflation and output targets, given the *incredulity bias* in the satisficing evolutionary dynamics of foresight strategy switching that arises as the ELB is approached. Meanwhile, in the absence of mutation ($\varepsilon = 0$), the (likewise unique) equilibrium solution is given by $\left(y^T, p^T, 0\right)$, with the achievement of the official inflation and output targets being accompanied by a configuration in which all agents have adopted the credulous strategy to form inflation and output expectations. Moreover, it follows from equation (3) that the fiscal policy variable represented

[11] The reference here is to the passage in the Bible involving the Apostle Thomas, who declined to believe that the resurrected Jesus had appeared to a group other apostles unless he, himself, could see and feel the injuries suffered by Jesus on the cross: "Unless I see the nail marks in his hands and put my finger where the nails were, and put my hand into his side, I will not believe it" (John 20: 19-29). In secular terms, incredulous agents respond to policy targets on a strict "seeing is believing" basis.

by the PSBR becomes stationary in the unique equilibrium configuration of the economy, which in conjunction with the stationarity of output at its official target value implies that the PSBR to output ratio is also stationary.

Let us now conduct the corresponding stability analysis. The Jacobian matrix evaluated around the equilibrium is given by:

(21) $$J\left(y^T, p^T, k^*\right) = \begin{bmatrix} -a & -b & 0 \\ -\alpha a & -c & 0 \\ 0 & 0 & -1 \end{bmatrix}.$$

We recall that $a \equiv \lambda\mu + \gamma(1-k^*) > 0$, $b \equiv \delta(1-k^*) + \lambda\psi > 0$, and $c \equiv (\varphi + \alpha\delta)(1-k^*) + \alpha\lambda\psi > 0$. Let ξ be an eigenvalue of the Jacobian matrix in expression (21). We can set the following characteristic equation of the linearization around the equilibrium:

(22) $$\left|J - \xi I\right| = \begin{vmatrix} -a-\xi & -b & 0 \\ -\alpha a & -c-\xi & 0 \\ 0 & 0 & -1-\xi \end{vmatrix}.$$

This characteristic equation can be re-written as follows:

(22-a) $$\left[\xi^2 + (a+c)\xi + a(c-\alpha b)\right](1+\xi) = 0,$$

whose solutions are the eigenvalues of the Jacobian matrix in expression (22), which are given by:

(23) $$\xi_1 = \frac{-(a+c) + \sqrt{(a+c)^2 - 4a(c-\alpha b)}}{2},\ \xi_2 = \frac{-(a+c) - \sqrt{(a+c)^2 - 4a(c-\alpha b)}}{2}, \text{ and } \xi_3 = -1 < 0.$$

As $a+c>0$ and $c-\alpha b=\varphi(1-k^{*})>0$ for all $k^{*}\in[0,1)\subset\mathbb{R}$, then $\mathrm{Re}(\xi_1)<0$ and $\mathrm{Re}(\xi_2)<0$ such that the unique equilibrium given by $\left(y^{T}, p^{T}, \frac{\varepsilon}{1+\bar{i}}\right)$ is locally asymptotically stable.

5. Discussion

At first sight, policy-making in the model faces an insoluble 'Tinbergen problem', in that policy makers can manipulate only a single instrument (fiscal policy) in the pursuit of two targets (for inflation and output). However, the model features the Tinbergen problem being ultimately solved, as there are two adjusting variables (viz. the expansionary-fiscal policy variable, g, and the private sector's degree of credulity in the effectiveness of policy-making, as measured by $1-k$), the coupled dynamics of which result in the achievement of the two targets as a stable equilibrium configuration. It follows that stabilization policy prosecuted adequately conducting fiscal policy as the single policy instrument can actually work in stabilizing the economy in accordance with the policy-makers' chosen policy targets.

In fact, full credulity in the effectiveness of policy-making can be interpreted as another implicit policy target, the achievement of which is a by-product of achieving the official targets for inflation and output (at least when $\varepsilon=0$). Interestingly, private agents actively contribute to effective fiscal policy by adopting heterogeneous strategies to form inflation and output expectations, and by possibly switching such strategies based on a boundedly rational, evolutionarily satisficing protocol. Therefore, endogenously time-varying heterogeneity in the strategies adopted by the private sector to construct inflation and output expectations in accordance with satisficing evolutionary dynamics may actually (albeit unintentionally) facilitate instead of impede successful target-based stabilization policy. Also, our analytical results show that inflation- and ouput-targeting may actually succeed in anchoring inflation and output expectations even if heterogeneity in the strategies adopted by private agents to form inflation and output expectations emerges as an equilibrium outcome of satisficing evolutionary dynamics. The intuition underlying this result is that despite there is heterogeneity in the strategies to form inflation and output expectations, the two available strategies yield the same prediction of such variables in the equilibrium configuration, which is characterized by the achievement of the policy targets for inflation and output. While incredulous agents form expectations in accordance with current inflation and output, credulous agents' expectations are firmly anchored to the official inflation and output targets. Fiscal policy contributes to the achievement of two policy targets at the ELB also by substituting for monetary policy as a way of affecting the expected real interest rate through expected inflation. In fact, fiscal policy, by having both a direct (via the fiscal policy rule) and an indirect effect (via inflation and output expectations), is able to engender changes in the expected real interest rate at the ELB.

However, our stability conditions reveal that fiscal policy achieves two targets with one instrument if $\varphi > 0$ – in other words, as long as there is a link between inflation and inflation expectations in equation (2). Hence observe that $\varphi = 0$, by breaking the link just noted, implies that $c - \alpha b = 0$ in equation (23), and the stability result reported above is lost. Intuitively, $\varphi = 0$ erodes the two-way interaction between the evolution of macroeconomic outcomes and the evolution of expectations in our model sufficiently to eliminate the indirect channel of adjustment through which (in part) a stabilization policy with two targets but just one (fiscal) instrument effectively works. Note also that we posit $0 < \varphi < 1$, giving our economy a Post-Keynesian structure. A more mainstream interpretation of the Phillips curve in equation (2) would posit $\varphi = 1$, consistent with full indexation of expected inflation into nominal wage growth (real wage bargaining). In this case, the equilibrium solution of equation (2) would yield $y = -\beta / \alpha$, and if we assume that $-\beta / \alpha = y_n = y^T$ (where y_n is the "natural" level of output determined on the supply-side of the economy), our analysis would be consistent with that arising from a mainstream New Consensus model. The point to be clearly made here is that $\varphi = 1$ does not affect the stability result derived earlier. In other words, our key policy result – that it is possible to achieve two targets with one (fiscal) policy instrument when operating at the ELB in the presence of heterogeneous, evolutionarily time-varying expectations – holds regardless of the precise (Post-Keynesian versus mainstream) specification of our underlying model.

As suggested in Section 2, the functional dependence of the expected real interest rate on inflation expectations means that unlike the (fixed) ELB, the lower bound on the expected real rate of interest is, itself, evolutionarily time-varying. In effect, it follows from equation (5) that the rate of change of this lower bound depends on both the deviation of inflation from its official target and the frequency distribution of strategies used to form inflation and output expectations in the private sector. Yet, although the lower bound on the expected real interest rate is evolutionarily time-varying, in principle, policy-makers can still *directly* affect the expected real interest rate at the ELB. To see this, note that it follows from equation (4) that $\dot{r}^e = -\dot{p}^e$, with which, using equation (5), can be used to express the rate of change of the expected real interest rate as follows:

(24) $$\dot{r}^e = (1-k)(p - p^T),$$

so that:

(25) $$\partial \dot{r}^e / \partial p^T = -(1-k) < 0 .$$

Recalling that $k \in [0,1] \subset \mathbb{R}$ denotes the proportion of incredulous agents (who form expectations in accordance with current inflation and output), it follows intuitively that the success of the policy authorities in engineering a temporary fall in the expected real interest rate by raising the inflation target is increasing in the proportion of credulous agents ($1-k$). Starting from a position of equilibrium, where

$\dot{r}^e = 0$ in equation (24), a rise in the inflation target p^T will result in $\dot{r}^e < 0$ for any $k^* \in (0,1) \subset \mathbb{R}$, which holds for all $\varepsilon \in (0,1) \subset \mathbb{R}$ and $\bar{i} \in \mathbb{R}_+$. In other words, the policy authorities can reduce the expected real interest rate at the ELB (and hence boost aggregate demand) simply by increasing their inflation target. However, this rise in the inflation target (which will be accompanied by an equivalent rise in the current rate of inflation once equilibrium is regained) may have negative side effects during the course of the system's transitional dynamics. In particular, it may, in and of itself, undermine agents' confidence in the inflation target as a potentially reliable conventional anchor for expectations.[12] Even a one-time and modest rise in the inflation target might undermine confidence in the inflation target as a reliable predictor of inflation, for reasons other than those already accounted for by the noisy satisficing evolutionary dynamics in equation (17).[13]

Finally, note that although both the ELB itself and the equilibrium proportion of credulous agents in the private sector are invariant with respect to the inflation target, they nevertheless affect the out-of-equilibrium dynamics associated with changes in p^T. Based on equations (20) and (24), we have that for all $\varepsilon \in (0,1) \subset \mathbb{R}$ and $\bar{i} \in \mathbb{R}_+$:

$$(26) \qquad \left.\frac{\partial \dot{r}^e}{\partial p^T}\right|_{k=k^*} = -(1-k^*) = \frac{\varepsilon}{1+\bar{i}} - 1 < 0 .$$

In other words, the magnitude of $\dot{r}^e$ immediately following a rise in the inflation target is decreasing in the mutation rate ε and increasing in the ELB on the nominal interest rate $\bar{i}$. Therefore, a lower ELB – in and of itself a good thing if monetary policy-makers are trying to reduce the real interest rate in

[12] It may also create the potentially-destabilizing expectation of further increases in the inflation target, leading private agents defer changes in behavior in favour of adopting a 'wait and see' approach.

[13] Note also that a permanently higher inflation target causes only a temporary boost in output (the equilibrium value of which remains equal to its official target value) at the cost of a permanently higher rate of inflation.

conventional fashion, by acting on its nominal rate – will actually *hamper* the authorities' ability to reduce the (expected) real interest rate further (by increasing the inflation target) once the ELB is reached.

6. Conclusions

The effective lower bound (ELB) on the nominal interest rate represents a potential constraint on stabilization policy based on the manipulation of conventional monetary policy instruments. However, the endogenous adjustment of the frequency distribution of strategies used by private-sector agents to form inflation and output expectations, when driven by satisficing evolutionary dynamics, serves to relax the constraint imposed by the Tinbergen (1952) principle at the ELB. This relaxation allows policy-makers to openly pursue and eventually achieve two official targets (inflation and output) making use of only one explicit instrument (countercyclical fiscal policy). The Tinbergen principle is only apparently violated in this situation, the reason being that the frequency distribution of strategies used to form expectations performs as another adjusting variable that ensures (as it co-evolves with fiscal policy) achievement of both policy targets as part of a stable equilibrium configuration. Moreover, in keeping with the empirical evidence, this equilibrium is characterized by heterogeneity in the strategies used to form inflation and output expectations in the private sector. Interestingly, a novel analytical result derived in the paper is that the equilibrium proportion of credulous agents (whose expectations are anchored to the official inflation and output targets) varies positively with the effective lower bound of the nominal interest rate. Therefore, the equilibrium proportion of credulous agents reaches its lowest possible strictly positive level when the effective lower bound is equal to zero.

Our analytical results reveal a second channel of fiscal policy transmission (in addition to standard aggregate demand effects) working through the evolutionarily time-varying frequency distribution of inflation- and output-forecasting strategies within the private sector – what might be dubbed an 'inflation-and output-predictor heterogeneity' channel. The operation of this channel suggests that endogenously time-varying heterogeneity in the strategies adopted by private agents to form inflation and output expectations may actively facilitate successful stabilization policy at the ELB, when the feasible set of policy instruments is constrained.

Whenever the possibility of using fiscal policy as a substitute for conventional monetary policy is contemplated, two frequently-raised concerns are: the existence of fiscal space; and the conditions for intertemporal fiscal sustainability.[14] Although these concerns are related, they are nonetheless logically distinct. Note also that concern with the existence of fiscal (or debt) space, allowing recourse to a fiscal variable such as the public-sector borrowing requirement (PSBR) as a policy instrument, is effectively analogous to concern about the (im)possibility of reducing the nominal interest rate in the presence of an ELB. Three comments are in order here. First, our specification of fiscal policy as countercyclical contributes to some extent to fiscal sustainability, in that with a countercyclical fiscal rule the fiscal policy variable is more likely to be stability-prone. In fact, the achievement of the official inflation and output targets accompanied by heterogeneity in the strategies used to form inflation and output expectations emerges as the unique and stable equilibrium configuration of the economy precisely because of the strictly countercyclical stance of the fiscal policy specified in the model. Second, the fiscal policy variable represented by the PSBR becomes stationary in the equilibrium configuration, which in conjunction with the stationarity of output at its official target level, implies that the ratio of the PSBR to output is also stationary. In fact, we can think of g^T as an implicit official target for the PSBR, the achievement of

[14] A third concern is with Ricardian equivalence. We would argue that concern with Ricardian equivalence is diminished in the model contemplated in this paper, wherein even in equilibrium, there is disagreement among the community of heterogenous private-sector decision makers as to whether or not output must conform to a specific exogenously-given value (associated with the public sector's output target). In other words, equilibrium outcomes in our model cannot be associated with a private sector that uniformly believes that the economy must revert to a specific level of output determined independently of public-sector aggregate demand management, which belief is implicit in models that give rise to behaviour consistent with Ricardian equivalence.

which is a by-product of the achievement of the official targets for inflation and output. Finally, the "public debt space" available for the pursuit of active fiscal policy is considerably higher at the ELB than at higher rates of interest, owing to the effects of the interest rate on public-sector debt dynamics. In short, we see no obvious reason as to why conventional objections to the use of fiscal policy would necessarily impede – much less preclude – its successful pursuit as envisioned in this paper.

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