

Companion Questionnaire for “A New Keynesian Workbook”

1. Static Models

Detailed discussion of the static models is available in Carlin and Soskice (2005) and Bofinger et al (2006). Interested readers should consult these papers for additional derivations and related issues. This questionnaire offers only a small sample of the more fundamental questions in the static setting, with the primary focus dedicated to the dynamic models. Some of the issues that are pertinent to both settings are discussed only in the static case to avoid repetition.

1.1 Static Instrument Model

Q: What are the possible sources of the cost-push shock?

A: The cost-push can come from several sources. First, it can be related to changes in prices of (exogenously modeled) inputs, such as oil, or take the form of endogenous disturbances related to the labor market (see Erceg, Henderson, and Levine (2000) or Blanchard and Gali (2006)). Second, it can be derived as a shock to the aggregating technology that combines the goods produced by the monopolistically competitive firms into a composite product consumed by the households or, more generally, as a disruption in the production process. Third, it can be modeled as the variability in the government taxes collected from firms. (See Steinsson (2003) for a detailed derivation of the last two effects.) In an open-economy setting, it can be modeled as fluctuations in imports prices due to variability in exchange rates (see Monacelli (2005) for a derivation of an endogenous shock due to incomplete-pass through). In endogenous cases, these shocks can be a consequence of other underlying disturbances, such as the technological shock.

Q: What effect does the cost-push shock have?

A: The cost-push shock shifts the AS schedule upwards, lowering the output gap and raising inflation. Ceteris paribus, higher inflation—which is given exogenously in the IS/MR model—will reduce the real

interest rate, shifting the IS schedule upwards, and motivate the central bank to raise the target nominal interest rate, shifting the MR schedule upwards. The AD schedule doesn't shift.

Q: What are the possible sources of the demand shock?

A: The demand shock can have a variety of sources; here are some (but not all) motivations. First, it can be modeled as a fiscal shock by assuming that output is split between consumption and government spending but the share of the latter in output is subject to disturbances; higher share of government spending in output produces a positive demand shock. Second, it can be described as a shock to household preferences; say, if agents become more inclined to consume now relative to the future, we have a positive demand shock. Third, in the baseline New Keynesian model, the shock can be described as the natural interest rate that is negatively related to the technological shock (alternatively, this can be related to the natural level of output); if the latter is positive, therefore, we have a negative demand shock. The intuition behind this is as follows: a positive technological shock increases the natural level of output and expands production. Prices should decline but since some firms do not reset them—this is the effect of nominal stickiness—they do so on aggregate by less than if prices were flexible. On net, this means that actual output falls below potential, hence the negative effect of a technological shock on the output gap. Note that in the traditional Keynesian models technological shocks have no effect on the aggregate demand schedule, whereas the general equilibrium setup of the New Keynesian model implies that it does. Finally, if the composite good consumed by the households contains imports, the demand shock can be modeled as an exchange rate disturbance; see Monacelli (2005) for a formal derivation in the case of incomplete pass-through.

Q: What effect does the demand shock have?

A: The direct effect of the demand shock is to shift the IS schedule upwards. The direct effect of the shock is represented by the shift from IS_0 to IS' ; it assumes that there are no changes in inflation. This shock, however, also shifts the AD schedule up generating higher inflation. This has a secondary effect

on the IS schedule (shifting it even higher, since higher inflation lowers the real interest rate) graphically represented by moving from IS' to IS1 and the MR schedule (since higher inflation raises the central bank's target nominal interest rate) graphically represented by going from MR0 to MR1.

Q: What are the possible sources of the monetary shock?

A: There are at least two ways of motivating monetary shocks. First, there exists a rather broad literature on the challenges that monetary policy-makers face in real time. (See Orphanides (2001) for implications of these challenges.) Therefore, their estimates of where the macroeconomic variables are may be off; these informational gaps would then give rise to monetary shocks. An alternative interpretation is that in practice central banks track a very large number of variables; hence their responses to those aggregates may give rise to monetary shocks relative to what would be motivated by output gap and inflation alone. Finally, monetary shocks are frequently referred to as the “non-systematic component of monetary policy” to emphasize that they constitute departures from what otherwise consistently describes policy conduct.

Q: What effect does the monetary shock have?

A: A contractionary shock raises the nominal interest rate shifting the MR schedule upwards. The shock's direct effect, assuming that inflation is constant, is represented by the shift from MR0 to MR'. The shock depresses the AD schedule, reducing both output gap and inflation. This new AS/AD equilibrium has two secondary effects on the IS/MR model. First, lower inflation shifts the MR schedule downwards, as the systematic component of monetary policy counters the effect of the non-systematic one; this is represented by moving from MR' to MR1. Second, it raises the real interest rate, which pushes the IS schedule downwards as well (from IS0 to IS1).

1.2 Static Targeting Model

Q: Why are monetary and demand shocks unimportant in the targeting model?

A: They are unimportant because the central bank is implicitly assumed to be able to detect them instantly and offset them by adjusting the interest rate accordingly. In the baseline specification, this volatility in interest rates happens costlessly. This assumption can be modified by assuming that interest rate volatility leads to social welfare losses due to, for instance, higher financial frictions, which would introduce a squared interest rate term in the objective (see Chapter 4 in Woodford (2003) for an explicit derivation). Alternatively, one can investigate the effect of interest rate volatility on firms' marginal costs (see the brief discussion of the cost channel of transmission of monetary policy in the appendix below). In either case, the aggregate demand equation will become an additional constraint in the welfare loss minimization problem.

Q: What role does the parameter α play?

A: It describes the importance of output gap volatility relative to inflation volatility. If $\alpha < 1$, the central bank cares more about inflation volatility than output gap volatility. This is the standard assumption in the literature; it corresponds to an elliptical welfare loss, elongated along the output-gap axis. When $\alpha = 0$, the central bank can be described as an “inflation nutter”, eliminating inflation volatility. If $\alpha = 1$, the central bank cares equally about inflation and output gap volatility; this corresponds to a circular welfare loss graph. If $\alpha > 1$, the central bank cares more about stabilizing output gap; this is described by an elliptical welfare loss, elongated along the inflation axis.

Q: Where does the welfare function come from?

A: The welfare function can be formally derived from the household preferences, as a second-order—to account for variability—approximation. (See Woodford (2003) for derivations of several variants.) Therefore, it is important to emphasize that the specification of the social welfare function should be related to the model's structural equations, which are also dependent on household preferences. (See Walsh

(2005) and Hanson and Kapinos (2006) for implications of this issue for optimal monetary policy.) The Dynamic Targeting Model section discusses the welfare function in more detail.

2. Dynamic Instrument Model

Q: What effect does the shock persistence parameter have on the four schedules?

A: As is described in the Technical Appendix, some of the effects associated with the shock persistence parameters are ambiguous. The unambiguous effects are as follows. Higher ρ 's make the AS schedule steeper, because inflationary expectations become more important. If the current inflation rate goes up in response to a positive shock, the future inflation rates can be expected to remain persistently positive. Since their discounted values are incorporated into current inflation, higher persistence produces a steeper AS slope. Higher ρ 's also make the slope of the IS schedule flatter, operating through higher expected inflation, which *ceteris paribus* reduces the real interest rate.

Q: What effect does the shock persistence parameter have on the impulse responses?

A: It increases the time of convergence back to initial conditions. Note that when the persistence parameter is set to zero, impulse responses last for only one period.

Q: What is the role of inflation and output gap coefficients in the monetary rule? What are the special cases?

A: γ_π and γ_x describe by how much the central bank will raise the nominal interest rate in response to expected inflation and current output gap, respectively. It is typically expected, rather than current, inflation is modeled in the interest rate rule, because the central bank's nominal interest target affects aggregate activity through the real interest rate and its effect on output gap. For this reason, system stability requires that $\gamma_\pi > 1$, otherwise monetary policy will not reduce output gap in response to higher inflationary expectations. Modeling a central bank that does not pay attention to output gap implies that $\gamma_x = 0$ and the MR schedule is flat. This is a popular assumption implicitly incorporated, for instance, by Romer (2000) into a model that is similar to the static variant discussed above.

Q: What role does the intertemporal elasticity of substitution play?

A: This parameter describes the household decision to substitute consumption tomorrow with consumption today, given the cost in the form of the real interest rate. High intertemporal elasticity of substitution (IES) implies that the households are fairly indifferent between consumption now and in the future. It also implies that they have a low degree of risk aversion (for a constant relative risk aversion utility function, the IES is the inverse of the relative risk aversion coefficient) and hence are relatively disinterested in smoothing consumption across time periods. IES has far-reaching implications for the successful conduct of monetary policy. Recall that the central bank affects aggregate activity through the real interest rate. Hence if the IES is very low, monetary policy conduct will be relatively ineffective. See Fuhrer and Rudebusch (2002) for an extensive exercise in estimating the aggregate demand relation and the IES.

Q: Where does the contemporaneous slope of the Phillips curve come from? What effect does it have in the model?

A: The Phillips curve can be derived as the firms' first-order condition for the profit maximization problem with respect to price. Firms are assumed to be able to set their own prices because they are monopolistically competitive. The popular Calvo (1983) pricing mechanism introduces nominal rigidities by assuming that firms face a probability $0 < \theta < 1$ that they cannot reset prices in a given time period. Therefore, when they get a chance to do so, they optimize with respect to the possibility that they may not get to reset the price again in the future time periods. This introduces the forward-looking component into the Phillips curve. The contemporaneous slope κ can be shown as a composite of preference parameters that characterize the household utility function and the Calvo probability θ . In particular, it can be demonstrated that κ is proportionate to $\frac{(1-\theta)(1-\beta\theta)}{\theta}$, which approaches 0 as θ approaches 1. Therefore, as firms become increasingly likely to be unable to reset prices, i.e. as the

degree of price stickiness increases, the slope of the Phillips curve becomes flatter. This has important implications for the model: For a given cost-push shock and aggregate demand, the increase in the equilibrium rate of inflation will be higher and the drop in the output gap larger, the flatter is the Phillips curve.

Q: Where does the discount factor come from?

A: It comes from the long run equilibrium in the economy (that describes how the economy grows, as opposed to evolves in response to temporary disturbances) and can be shown to be inversely related to the real interest rate that prevails in the long term.

Q: What aspects/modifications of the New Keynesian model are discussed in the literature?

A: Dynamics in this baseline model entirely rely on the persistence of an exogenous shock. More realistic treatments would incorporate some endogenous persistence, whereby current levels of variables depend on their lags. For instance, Clarida et al. (1999) emphasize that the behavior of nominal interest rates suggests that the Fed smooths them, which can be modeled by introducing a lag into the specification. Measures of output gap also exhibit considerable persistence, which motivates introduction of lagged terms into the aggregate demand specification; see Fuhrer and Rudebusch (2002) for empirical estimates. Finally, there is considerable debate on relative weights of forward- and backward-looking inflationary terms in the Phillips curve, which are critical for the propagation of the cost-push shock that introduces a tradeoff between inflation and output gap. See Gali and Gertler (1999) for an early empirical investigation of this issue.

3. Dynamic Targeting Model

Q: How does volatility in inflation and output gap generate social welfare losses?

A: The representative household utility function in the baseline New Keynesian model has two terms: consumption and labor supply. (In the simplest version, the two terms are additively separable and have constant relative risk aversion functional form.) The term with respect to consumption is going to vary

together with output (given the market clearing condition); moreover, since prices are sticky, households' optimal consumption bundles will be different from what they would have been had prices been flexible. This source of welfare losses is captured by some x_t^2 term (or the output gap variance). The second term that matters in the utility function has the household labor supply. It gives rise to two sources of variability. First, using the production function that has labor as an input, it can also be related to output gap, hence there is an x_t^2 term here as well. Second, as households supply their labor to different firms, they will experience some disutility from the fact that firms may demand varying amounts of their labor depending on whether or not they were able to reset prices in a given time period. This provides a link to the measure of cross-sectional variability in firms' pricing decisions, i.e. inflation. Hence the social welfare function measure volatility in two terms—output gap and inflation—linking them to variability in household consumption and labor supply

Q: Why are the social welfare losses under discretion larger than under commitment?

A: Persistent shocks continue to generate deviations from the steady state (and welfare losses) even after the time period when the initial impulse occurs. This is reflected in the agents' expectations. But under discretion, the central bank does not incorporate these expectations and future welfare losses into its decision-making, since it is concerned only with the current time period. Over time, this discretionary “myopia” amounts to higher welfare losses.

Q: Why is commitment time inconsistent? How can the central bank act discretionarily so that the social welfare loss is minimized over time?

A: As is discussed in more detail in the main paper, once the initial impulse has passed, the central bank has an incentive to abandon commitment and revert to discretion, because it would generate lower welfare losses. Therefore, commitment is time inconsistent. A central bank can avoid this problem by announcing that it will follow a certain rule discretionarily by minimizing over an objective that is different from the true social welfare loss. Popular targeting rules discussed in the literature entail

replacing the output gap volatility term with volatility in another variable: prices, nominal income growth, or output gap growth. See Walsh (2003) and Kapinos and Hanson (2006) for a detailed discussion of the relative superiority of these rules.

References:

(Note only the references not mentioned in the main paper are listed below.)

- Erceg, C., D. Henderson, and A. Levine (2000). "Optimal Monetary Policy with Staggered Wage and Price Contracts." *Journal of Monetary Economics*, 46, 281-313.
- Fuhrer, J. and G. Rudebusch (2004). "Estimating the Euler Equations for Output." *Journal of Monetary Economics*, 51, 1133-1153.
- Gali, J. and M. Gertler (1999). "Inflation Dynamics: A Structural Econometric Analysis." *Journal of Monetary Economics*, 44, 195-222.
- Hanson, M. and P. Kapinos (2006). "Intrinsic Persistence and the Performance of Inertial Targeting Rules." Manuscript.
- Monacelli, T. (2005). "Monetary Policy in a Low Pass-through Environment." *Journal of Money, Banking, and Credit*, 37, 1047-1066.
- Orphanides, A. (2001). "Monetary Policy Rules Based on Real-time Data." *American Economic Review*, 91(4), 964-985.
- Ravenna, F. and C. Walsh (2006). "Optimal Monetary Policy with the Cost Channel." *Journal of Monetary Economics*, 53, 199-216.
- Steinsson, J. (2003). "Optimal Monetary Policy in an Economy with Inflation Persistence." *Journal of Monetary Economics*, 50, 1425-1456.
- Walsh, C. (2003). "Speed Limit Policies: The Output Gap and Optimal Monetary Policy." *American Economic Review*, 93, 265-278.
- Walsh, C. (2005). "Endogenous Objectives and the Evaluation of Targeting Rules for Monetary Policy." *Journal of Monetary Economics*, 52, 889-911.

Appendix: Possible Extensions

Extension 1: Backward- vs. Forward-Looking Aggregate Supply

The dynamic propagation mechanism of baseline model consisted of two elements: rational expectations of future events and persistence in the exogenous shock. The latter may not be entirely satisfactory because it skirts the issue of the exact source of such persistence. At the same time, persistent dynamics of macroeconomic variables have drawn considerable attention from researchers. A popular way of modeling this is by introducing lagged endogenous terms. Since the focus of this paper has been on the effect of the cost-push shock on inflationary dynamics, only the aggregate supply relation will be modified to introduce endogenous persistence in inflation. The relation becomes:

$$\pi_t = \omega\beta E_t \pi_{t+1} + (1 - \omega)\pi_{t-1} + \kappa x_t + v_t, \quad (12)$$

where v_t is now (non-persistent) white noise and ω measures the degree of forward-looking (vs. backward-looking) behavior for price setters. The appearance of the lagged inflation term is typically motivated by allowing some firms who cannot set prices in the rational, forward-looking fashion to index their prices to last period's inflation, which can be observed by all agents in the economy. For simplicity, the model can be closed by assuming that the central bank uses (10) as its "leaning-against-the-wind" rule. Note that the impulse response of inflation to a cost-push shock is going to be sharper and will dissipate faster, if the firms are primarily forward-looking. Conversely, if firms are predominantly backward-looking, the impulse response is going to be more muted but will propagate longer.

Extension 2: Cost Channel of Transmission of Monetary Policy

Figure 5.11 in Blanchard (2006) demonstrates the positive response of prices to a contractionary monetary policy shock from Christiano et al. (1996). Following the work of Sims (1992), the phenomenon has been termed "the price puzzle". One explanation of this puzzle that has received considerable attention in the literature is the so called cost channel of transmission of monetary policy, whereby the interest rate enters the per unit marginal cost function of a firm as it models the cost of working capital or the firms' borrowing to finance wage expenditures. (See Ravenna and Walsh (2006) for the discussion of the latter assumption, as well as empirical estimates of the cost channel's extent.) The aggregate supply relation (4) has to be modified as follows to account for this effect:

$$\pi_t = \beta E_t \pi_{t+1} + \kappa x_t + \chi i_t, \quad (13)$$

where the parameter χ characterizes the extent of the cost channel's presence. Aggregate demand (3) and the monetary policy rule (5) complete the model. In the absence of the cost channel ($\chi=0$), we obtain the standard result that inflation declines in response to the monetary contraction. However, as χ increases and higher interest rates begin to impose larger costs on producers requiring them to raise prices, the response of inflation becomes positive and increases with χ . One downside of this simple model is its inability to generate any decrease in inflation following the initial rise: The negative effect of higher interest rates on aggregate demand never dominates their positive (given the cost channel) effect on prices. This issue can be addressed by considering a model with richer demand dynamics.