Advanced Macroeconomics II: Assignment II

by Sannah Tijani & Fynn Lohre June 13, 2023

We hereby declare that the answers to the given assignment are entirely our own, resulting from our own work effort only. Our team members contributed to the answers of the assignment in the following proportions:

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Problem 1

Transmission of Monetary Policy Shocks in the AS-AD Model and the New Keynesian Model

- Draw a diagram of an AS-AD model for the case of an AS curve with a mild upward slope. Do not forget to label all axes and curves. Now, consider the case of an expansionary monetary policy shock. Which curve shifts where (IS-LM diagram is not needed), and what are the effects on output and the price level? What happens in the short-run and what in the long-run? Why?

- Redo the same as in exercise 1a) but with a with an AS curve that has a much steeper slope. Explain what are the differences and why do they arise between the mild-slope case and the steep-slope case and how we can interpret them economically?

- Recall that the NKPC from the baseline New Keynesian model from class is given by:

$$\hat{\pi}_t = \kappa(\hat{y}_t - \hat{y}_t^{flex}) + \beta E_t \hat{\pi}_{t+1}$$

  where $\kappa = \lambda(\sigma + \phi)$ and where $\lambda = \frac{\theta - 1}{\phi}$ under the assumption of Rotemberg price adjustment costs. What happens to the slope of the NKPC as prices become more flexible (lower price adjustment cost parameter ϕ) or as market power of monopolistic competitors decreases (higher elasticity of substitution between varieties, θ). How do your answers here relate to answers from question a.) and b.)? Under which parameter constellations (of ϕ and θ) does monetary policy have large short-run effects?

AS-AD & the Expansionary Monetary Policy Shock

Baseline Case

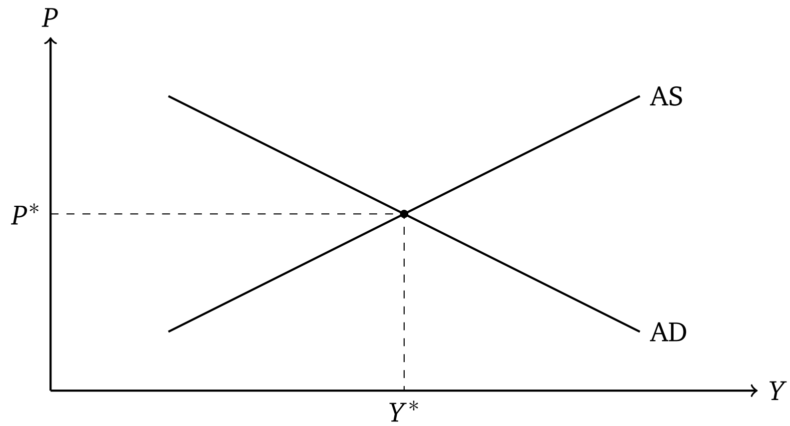

Figure 1: Initial State - Equilibrium, AS-AD Model

The initial state is represented by the equilibrium output, denoted as Y^*, and the equilibrium price level, denoted as P^*. At this point, the aggregate demand (AD) curve intersects with the aggregate supply (AS) curve, signifying the balance between the total demand for goods and services and the total supply available in the economy.

Now, let's consider an expansionary monetary policy shock, such as an increase in the monetary supply ($M_0 < M_1$). It is known that aggregate demand depends positively on the real money balance, expressed as $\frac{M}{P}$. In the aggregate demand equation ($AD : Y = Y(\underset{+}{M * P^{-1}}, \underset{+}{G}, \underset{-}{T})$), an increase in the real money balance is associated with a positive effect on aggregate demand. Assuming other factors remain constant (*ceteris paribus*), we observe an upward shift of the AD curve, denoted as AD', leading to a new equilibrium output level of Y^{**} and a corresponding price level of P^{**}.

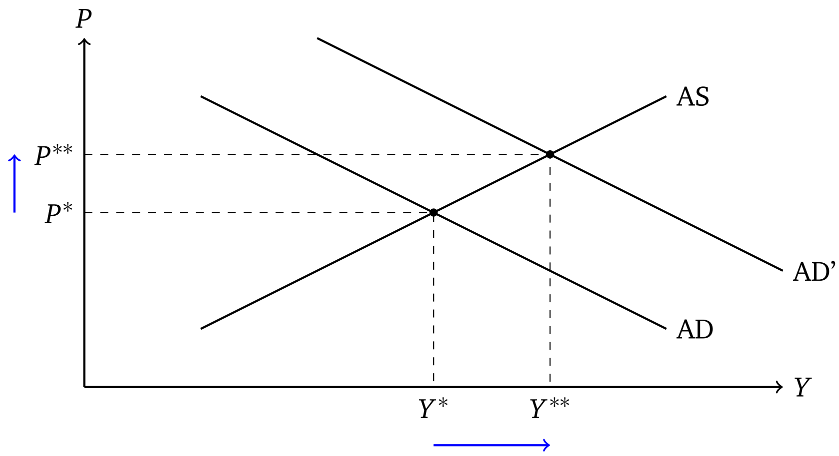

Figure 2: Short-run Effect Expansionary Monetary Policy, AS-AD Model

As visible, both P^{**} and Y^{**} are higher than before. This indicates the **short-run effect** of the expansionary monetary policy, highlighting the non-neutrality of monetary policy in the short run.

However, in the **long-run**, households expect the price level to be at P^{*}, while we have the higher price level of P^{**} due to the expansionary shock. Thus, the expected price level P_E is below the actual one. As the AS curve depends on the expected price level (and the output gap; as $AS : P = P_E F(Y - Y^{*})$), it follows from a sequential adjustment of the the households' expectations to the higher price level, that also the AS curve must *ceteris paribus* shift.

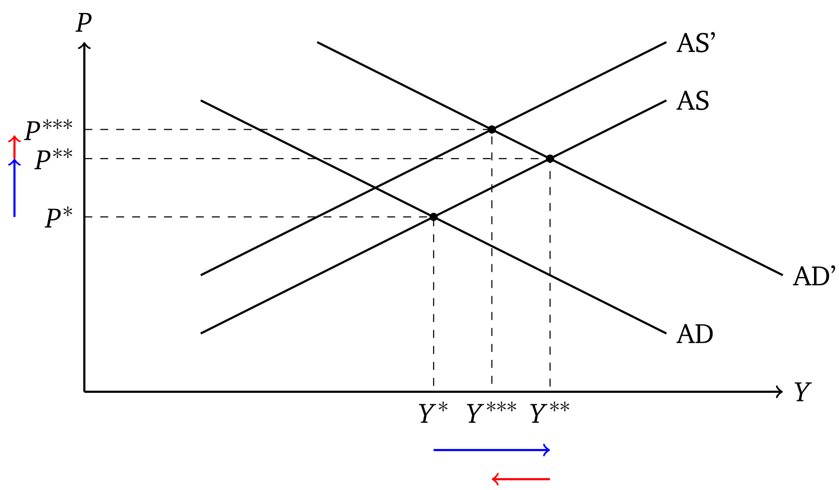

Figure 3: Long-run Adjustment Expansionary Monetary Policy, AS-AD Model

After the first adjustment of the households (see Figure 3) a new equilibrium of Y^{***} (lower than Y^{**}) and P^{***} (higher than P^{**}) emerges. As P_E changes to P^{**}, and, thus, again to lower price level than the actual one, implying that the households have to adjust again. This adjustment repeats, with diminishing effect, until no more adjustment is needed since P_E equals the actual price level. This overall effect of the sequential adjustments - the **long-run effect** - is shown in Figure 4:

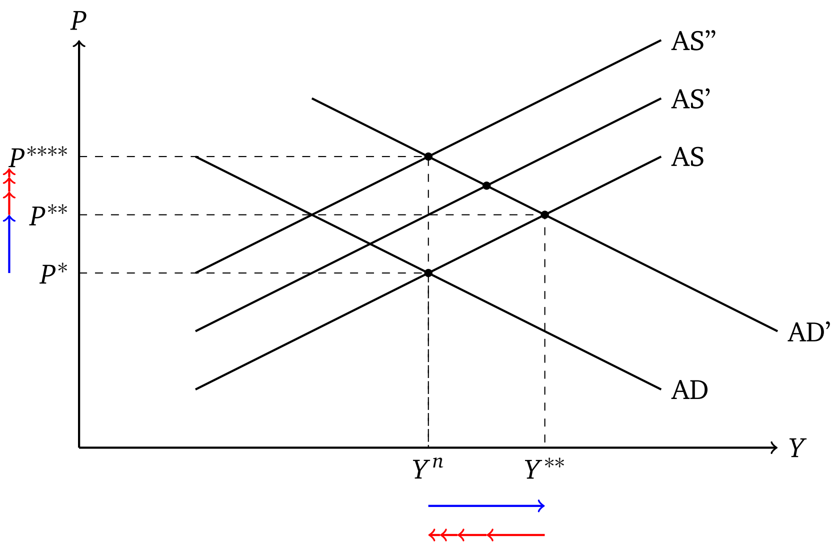

Figure 4: Long-run Effect Expansionary Monetary Policy, AS-AD Model

It’s visible that in the long run following the expansionary monetary policy the AS-curve shifted c.p. from AS to AS” and the AD-curve from AD to AD’. This implies in our standard scenario, that the price price level increase from P^{*} to P^{****}, while the output stays at Y^{*}, which is why the initial state is often called Y^{n}. Thus, monetary policy is neutral w.r.t. the output in the long run.

Steeper AS Curve

In Figure 5 we can see the overall long-run effect, given a steeper AS-curve. In general, in the short-run, a steeper AS-curve means that the relationship between output and the price level is more sensitive or responsive. In other words, a given change in the output will result in a larger change in the price level. It indicates that there is less spare capacity in the economy, and firms are less able to increase output without experiencing upward pressure on prices. This could be due to factors such as limited availability of resources, higher production costs, or production bottlenecks.

In practical terms, a steeper AS curve implies that the economy has less flexibility to respond to changes in aggregate demand (AD) in the short-run. Increases in AD may in the short-run lead to a relatively larger increase in prices and a smaller increase in output compared to a flatter AS curve.[1] As visible in Figure 5, the long-run (overall) effect is, nevertheless, similar.

From a policy perspective, a steeper AS curve implies that it may be more challenging to achieve higher levels of output without triggering inflationary pressures. It suggests that the economy may be operating

[1] The blue ”short-run arrows” in Figure 5 are *ceteris paribus* smaller w.r.t Y and larger w.r.t P compared to Figure 4.

closer to its potential or full capacity, and increasing output beyond that level could lead to inflationary consequences. However, the presence of a steeper AS curve also brings about an advantageous implication. In the pursuit of lowering the price level ("contractionary monetary policy"), this scenario is more suitable as it results in diminished adverse short-run effects on output in comparison to a situation characterized by a flatter AS curve (e.g. an inverse scenario of Figure 4 compared to an inverse scenario of Figure 5).

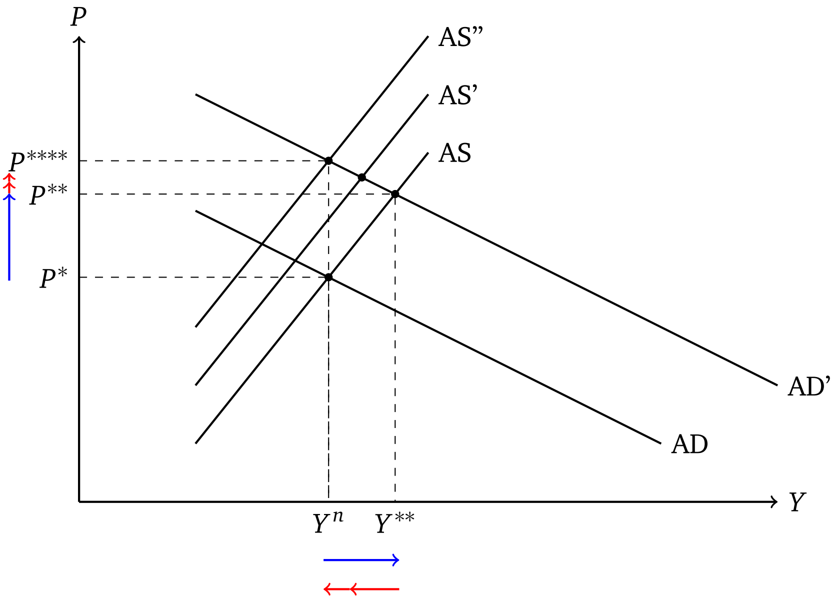

Figure 5: Long- & Short-run Effect Expansionary Monetary Policy, AS-AD Model with Steeper AS Curve

NKPC Changes

In the NKPC equation $\hat{\pi}_t = \kappa(\hat{y}_t - \hat{y}_t^{flex}) + \beta E_t \hat{\pi}_{t+1}$, the slope of the NKPC is determined by the parameter κ, which is a function of the price adjustment cost parameter ϕ and the elasticity of substitution between varieties θ. In the following, the effects of changes in ϕ and θ on the slope of the NKPC are analyzed and their relation to the answers from questions a) and b):

Price Flexibility (ϕ): As prices become more flexible (lower ϕ), the slope of the NKPC becomes steeper. This implies that a given change in the output gap ($\hat{y}_t - \hat{y}_t^{flex}$) leads to a larger change in inflation ($\hat{\pi}_t$). When price adjustment costs are low, firms can adjust prices more quickly, resulting in a stronger relationship between output and inflation. This relates to the short-run effects visible in questions a) and b) and the policy perspective of monetary policy discussed in question b) w.r.t. to a steeper AS curve.

Market Power (θ): As market power decreases (higher θ), the slope of the NKPC becomes flatter. This implies that a given change in the output gap has a smaller impact on inflation. When firms face more competition and have less market power, they have limited ability to raise prices in response to changes in the output gap. Consequently, the relationship between output and inflation weakens. Hence, the market power decrease coincides (has to coincide) with a *ceteris paribus* flatter AS curve, as the short run effect on inflation is much smaller (analogous to b) and respective policy perspective).

The parameter constellations of ϕ and θ that result in larger short-run effects of monetary policy, similar to the steeper AS curve of b), are when price adjustment costs (ϕ) are lower (indicating higher price flexibility) and market power is higher (lower θ, indicating lower elasticity of substitution between varieties). In such cases, changes in monetary policy have a more significant impact and inflation in the short run (analogous to a steeper AS curve).

To summarize, the slope of the NKPC becomes steeper as prices become more flexible (lower ϕ) and flatter as market power decreases (higher θ). Lower price adjustment costs and higher market power amplify the short-run effects of monetary policy. These findings align with the discussions in questions a) and b) regarding the short-run and long-run effects of monetary policy in the AS-AD model an the respective policy perspective.

Problem 2

A New Keynesian Model with Energy

- [...] Firms are now assumed to produce using both labor and energy as production inputs, according to a Cobb-Douglas production function:

$$Y_t(i) = A_t N_t(i)^{1-\alpha} EN_t(i)^{\alpha}$$

  The firms dynamic problem continues to read:

$$max \quad E_0 \sum_{t=0}^{\infty} \Lambda_{0,t} \left[P_t(i) Y_t(i) - MC_t Y_t(i) - \frac{\phi}{2} \left(\frac{P_t(i)}{P_{t-1}(i)} \right) \right]$$

  However, the definition of marginal cost, MC_t has changed. For your convenience, you do not need to derive the dynamic FOC w.r.t. the choice of the optimal price, as this is identical as in the baseline NK model. Instead, you only need to solve the changed cost minimization problem below, which now requires deriving the FOC w.r.t. $N_t(i)$, $EN_t(i)$, and $MC_t(i)$:

$$min \quad W_t N_t(i) + P_t^E EN_t i - MC_t(i) \left[A_t N_t(i)^{1-\alpha} EN_t(i)^{\alpha} - Y_t(i) \right]$$

  Where P_t^E denotes the (nominal) price of energy, which we will take as exogenously given (i.e. we do not model a supply side for energy, and instead assume that energy is imported from abroad at price P_t^E).

  - Label the FOC of the above expenditure minimization problem w.r.t. $N_t(i)$, $EN_t(i)$, and $MC_t(i)$ equations eq1), eq2) and eq3).
  - Show that one can derive the optimal labor-to-energy ratio from combining equations eq1) and eq2), and that this ratio only depends on (aggregate) prices, so that the ratio is not firm-i specific.
  - Show that one can derive an expression for marginal costs that also is the same for all firms i, by combining all three optimality conditions (that is, by expressing $N_t(i)$ from eq1 and $EN_t(i)$ from eq2 and plugging them in into the production function, eq3) to obtain the relevant expression for $MC_t(i)$. From now on, assume that all firms are identical, so that we can drop the i index.

- Code up the non-linear version of the energy-extended NK model in Dynare.
- Derive IRF to a i) monetary policy shock and ii) a technology shock. How do they qualitatively differ from the baseline model we have seen in class? Also, iii) present impulse responses to a energy price shock and discuss what and why happens to the macro-economy.

The NK Model with Energy

$$Min \quad W_t N_{t(i)} + P_t^E EN_{t(i)} - MC_{t_(i)}[A_t N_{t(i)}^{1-\alpha} EN_{t(i)}^{\alpha} - Y_{t(i)}] \tag{1}$$

$$FOC \quad w.r.t \quad N_t: \quad W_t - (1-\alpha)MC_{t(i)} A_t N_{t(i)}^{1-\alpha-1} EN_{t(i)}^{\alpha} = 0 \tag{2}$$

$$FOC \quad w.r.t \quad EN_t: \quad P_t^E - \alpha MC_{t(i)} A_t N_{t(i)}^{1-\alpha} EN_{t(i)}^{\alpha-1} = 0 \tag{3}$$

$$FOC \quad w.r.t \quad MC_t: \quad A_t N_t t(i)^{1-\alpha} EN_{t(i)}^{\alpha} - Y_{t(i)} = 0 \tag{4}$$

To find the labor-to-energy ratio, we solved equations 1 and 2 to isolate Mc_t. Then, we equate both equations and find the following result: From the FOC w.r.t. to N_t:

$$MC_{t(i)} A_t = \frac{W_t}{(1-\alpha) N_{t(i)}^{-\alpha} EN_{t(i)}^{\alpha}} \tag{5}$$

From the FOC w.r.t to EN_t:

$$MC_{t(i)} A_t = \frac{P_t^E}{\alpha N_{t(i)}^{(1-\alpha)} EN_{t(i)}^{(1-\alpha)}} \tag{6}$$

We then get:

$$\frac{P_t^E}{\alpha N_{t(i)}^{(1-\alpha)} EN_{t(i)}^{(1-\alpha)}} = \frac{W_t}{(1-\alpha) N_{t(i)}^{-\alpha} EN_{t(i)}^{\alpha}} \tag{7}$$

By simplifying we can express the labor-to-energy ratio as:

$$\frac{(1-\alpha)P_t^E}{\alpha W_t} = \frac{N_{t(i)}}{EN_{t(i)}} \tag{8}$$

Given that neither P_t^E not W_t are firm-specific we can see that the labor-to-energy ratio does not depend on the characteristics of the firm but is the same across all firms.

To compute the marginal cost we first find an expression for Nt from the eq1:

$$N_t = \frac{(1-\alpha) MC_{t(i)} Y_{t(i)}}{W_t} \tag{9}$$

We do the same for the energy using equation 2:

$$EN_{t(i)} = \frac{\alpha MC_{t(i)} Y_{t(i)}}{P_t^E} \tag{10}$$

Inserting the ratio into the production function we get:

$$Y_{t(i)} = A_t \left(\frac{(1-\alpha) MC_{t(i)} Y_{t(i)}}{W_t}\right)^{1-\alpha} \left(\frac{\alpha MC_{t(i)} Y_{t(i)}}{P_t^E}\right)^{\alpha} \tag{11}$$

$$Y_{t(i)} = \frac{A_t MC_{t(i)} Y_{t(i)} (1-\alpha)^{1-\alpha} \alpha^{\alpha}}{W_t^{1-\alpha} (P_t^E)^{\alpha}} \tag{12}$$

$$\frac{1}{MC_{t(i)}} = \frac{A_t (1-\alpha)^{1-\alpha} \alpha^{\alpha}}{W_t^{1-\alpha} (P_t^E)^{\alpha}} \tag{13}$$

$$MC_{t(i)} = \frac{1}{A_t}(\frac{W_t}{1-\alpha})^{1-\alpha}(\frac{P_t^E}{\alpha})^{\alpha} \tag{14}$$

We can see that the marginal cost of firm i does not depend on any parameter specific to firm i. In other words, the marginal cost is the same for all firms.

Dynare

We need to derive the participation constraint to adapt the code to our model taking energy into account. We use the market clearing condition:

$$P_t C_t + Q_t B_t = B_{t-1} + W_t N_t + T_t \tag{15}$$

using the fact that the market is in equilibrium we can simplify the equation:

$$P_t C_t = W_t N_t + T_t \tag{16}$$

$$C_t = \frac{W_t}{P_t} N_t + \frac{T_t}{P_t} \tag{17}$$

Using the real profit equation provided:

$$C_t = \frac{W_t}{P_t} N_t + Y_t - \frac{W_t}{P_t} N_t - \frac{P_t^E}{P_t} EN_t - \frac{\phi}{2}(\pi_t - 1)^2 Y_t \tag{18}$$

$$C_t = Y_t - \frac{P_t^E}{P_t} EN_t - \frac{\phi}{2}(\pi_t - 1)^2 Y_t \tag{19}$$

$$C_t + \frac{P_t^E}{P_t} EN_t + \frac{\phi}{2}(\pi_t - 1)^2 Y_t = Y_t \tag{20}$$

IRF of a Monetary Policy, a Technology Shock and a Energy Price Shock

In the following are our estimated IRF of a Monetary Policy Shock, a Technology Shock as well as an Energy Price Shock.

Monetary Policy Shock

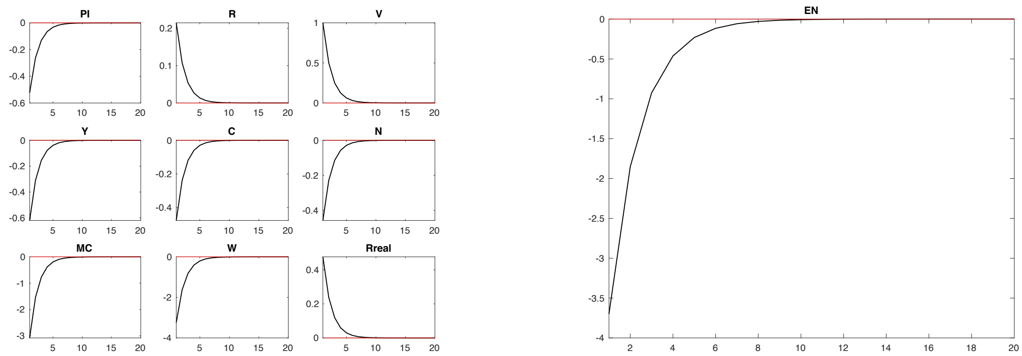

Figure 6: Monetary Policy Shock (unit shock, 20 periods, order=1)

Our estimated impulse responses for 20 periods show the effect of a contractionary monetary shock. Such a shock results in an increase in both nominal and real interest rates (given the positive correlation within the interest rule equation of v_t). As the shock creates an incentive to save in the economy, due to the increased returns, households decrease their current consumption by approx. 0.5 units in response to a unit shock (leading to an increased future discounted consumption).

This reduction in consumption leads to a decrease in output of 0.06 units as the aggregate demand reduces while the supply side remains unchanged. Thus, firms that cannot adapt their price immediately need to reduce both production inputs, which reflects the fact that real variables react to a change in monetary policy shock in the first few periods. The reduction in employment pushes the real wage downwards negatively affecting the marginal cost (-3 units in period 1).

Additionally, this reduction in output leads to a reduction in the output gap. Given that inflation depends positively on the output gap, we also observe a reduction in inflation, which is, however, insufficient to counteract the decrease in consumption. This is a good example of the non-neutrality of the monetary policy instrument in the case of sticky prices where the output level is affected by a monetary policy.

In the case of flexible prices, we would have observed a reaction of the firm able to reduce their price, such that the supply will adapt to the new macroeconomic environment. The result would be a reduction in inflation sufficient to counteract the incentive to save. Thus, consumption will start rising which will lead to a return of output to the level pre-shock. Thus in the baseline flexible case model, monetary policy is neutral.

Technology Shock

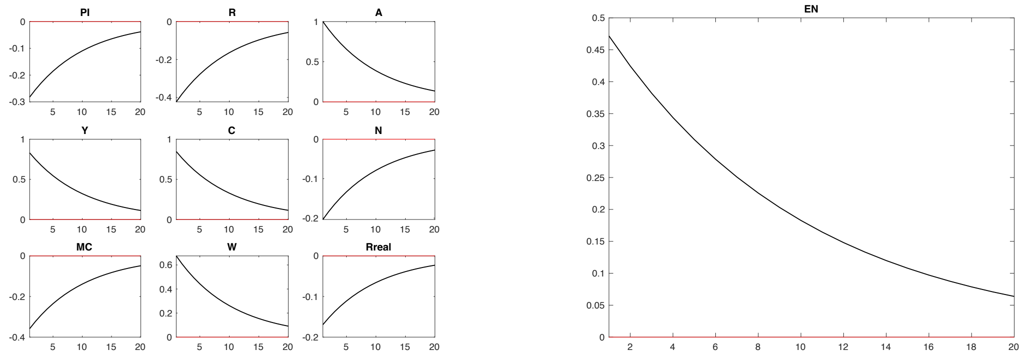

Figure 7: Technology Shock (unit shock, 20 periods, order=1)

A one unit positive TFP shock leads, according to the estimated IRF (20 periods) based on the previous model, to an output increase, that is approx. 0.8 units in the first period and diminished slightly but stays over zero in every period estimated. In case of of flexible prices we would expect it to be exactly one unit. However, given the boost in production, firms want to produce more but the price stickiness scenario implies, that the prices faced by the households are too high. Thus, they will not buy all additional output, as the price is not decreasing immediately. We are then confronted by a simultaneous increase in supply and reduction in demand. This distortion leads to an increase in output which is still positive, but less than the anticipated effect given flexible prices.

Additionally, the wage rate, which depends positively on the level of output, increases with the shock. The households face two choices, (i) they can either increase their working time as the wage is higher or (ii) they can work less and still keep their wages constant. This respectively reflects the substitution and income effects. In the case of flexible prices, they would both be equal and employment would, hence, be unaffected by the shock. However, as we can see in the impulse response, unemployment is decreasing, implying a higher income effect, which is due to the demand drop (caused by the non-adjustment of prices). Given the labor-to-energy ratio equation, the firm's reaction there is an increase of energy used for production, as employment becomes more expensive while the price of energy (exogenous) is unaffected. Finally, we see that the monetary policy accommodates the shock by decreasing the nominal interest rate which leads to a decreased level of inflation and real interest rate to close the change in the output gap.

Energy Price Shock

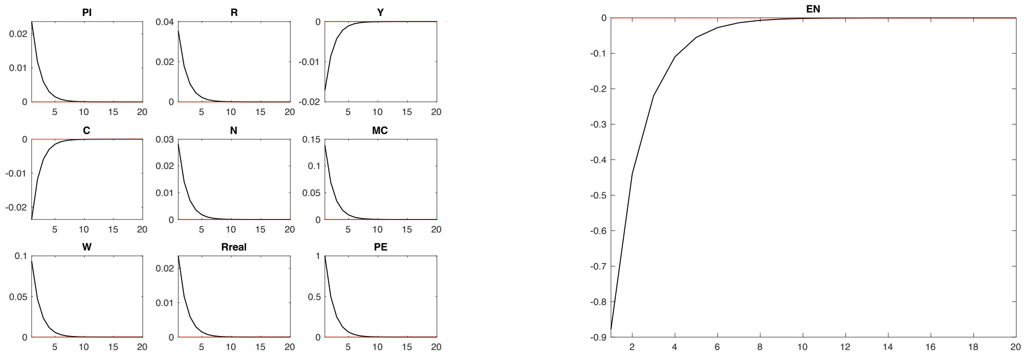

Figure 8: Energy Price Shock (unit shock, 20 periods, order=1)

We can observe in our estimated IRF (20 periods) that following an unit energy price shock (increase of 1 unit/percent), the productivity of the respective economy can c.p. only produce the same output with higher costs. As a result, the level of output decreases in the short run by 0.1 units, whereas the medium-run-effect (c.a. 10 years+) is close to zero. As the price of energy is increasing its consumption is decreasing by close to 1 unit. The marginal cost of the firms is also increasing, however, due to the substitution away from energy towards the other production factor, labor, this effect is less than 1 unit. Thus, employment itself increases for 0.03 units which lead to an increase in wages. In contrast to Assignment I[2], we can not estimate in our model any consumption smoothing and see the output gap fully as a "consumption gap" of -0.02 units. We also observe an increase in the marginal cost (0.15) as the price of energy is increased. As inflation is a function of the output gap, which is itself a function of the marginal cost, we observe an increase of inflation. As a result, we experience a rise in both real and nominal interest rates. This provides an incentive to households to reduce consumption, which also explains a share of the decrease in output. However, it is important to note that the deviation from the steady state in the case of an energy price shock is very low in magnitude when compared with the technology and the monetary shock. Additionally, we can see that overall, w.r.t. to its persistence, the Energy Price Shock is comparable to the Monetary Policy Shock, while a Technology Shock is much more persistent.[3]

If we compare this model with energy as an input into the production function to a model where labor is the only factor of production there is no qualitative change between the 2. Indeed, adding energy does not result in qualitatively different impulse responses.

[2]We estimated a basic RBC Model with an energy price shock there.
[3]At least according to the model and the estimated IRF; which is very interesting w.r.t. AI and its possible impact.

Problem 3

Policy Application

Listen to the interview of Ricardo Reis (LSE) on VoxEU on "How did inflation get so high? In a brief statement or mini-essay of about 300 words (e.g., suppose you work at a central bank and need to consult/brief your superior/governor), talk about a key insight or interesting aspect that you take away from this interview. In how far does this insight/aspect relate to what you have learned on monetary policy in the baseline New Keynesian model or goes beyond it?

NKPC equation:

$$\hat{\pi}_t = \lambda(\sigma + \varphi)(\hat{y}_t - \hat{y}_t^{flex}) + BE_t\hat{\pi}_{t+1} \tag{21}$$

According to Reis (2022), the current period of high inflation is due to a combination of 4 factors. Firstly, since the COVID-19 pandemic, several considerable shocks hit the economies. In response, central banks implemented stimulative monetary policies. Hence, the unexpected rapid recovery of the economies led to an increase in aggregate demand such that the output gap was raised. Unable to counteract their policy given the forward guidance of 2020, the level of prices rose. This is coherent with our NKPC where inflation depends positively on the output gap.

Secondly, the expectation of inflation is another determinant of the current level in the NKPC framework. The recent shock in energy prices incurred by households combined with the absence of reactions of central banks toward inflation resulted in a change in inflation expectation. This shift from anchored expectation (due to 20 years of stability) to un-anchored expectation produced an increase in the current level of prices. Therefore, the current un-anchored expectation of inflation from households and firms transformed temporary shocks into persistent effects.

Thirdly, the effect of the shift of expectation can be limited to short run as long as the credibility of central banks remained unaffected (measured financially). However, the shocks led to an increased probability of participants being insured against inflation persistent, thus loss of credibility. The effect is characterized by Reis as "facing an unfavorable and steep Phillips curve" and leading to long-term inflation increase. This increase in financial market participants in the possibility of inflation persistence relates to the NKPC by increased inflation expectation.

Finally, the focus of central banks on fighting potential deflation led to a large tolerance too high inflation and late to no policies implementation to counteract it. Thus, the effect of the increased output gap and increased inflation expectation without adequate monetary policy tools result in the current high level of inflation. This is consistent with the NKPC.