Optimal Monetary Policy in an Estimated DSGE Model for Hungary
First Draft

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Abstract

We explore the properties of optimal monetary policy in a medium-scaled DSGE model for Hungary. Our framework is a two-sector, open-economy, with imports as intermediate input to production. Our results suggest that by increasing openness, optimal policy becomes more concerned for stabilizing inflation. We also find that way imports are modeled is crucial for the normative implications of terms-of-trade shocks. That is, while it is optimal for the monetary policy to look over international relative price changes if imports are final consumption goods, it no longer applies once they enter into production.

1 Introduction

1.1 Motivation

A theoretically appealing feature of dynamic stochastic general equilibrium (DSGE) models is the existence of a well-defined welfare measure (i.e. utility). Consequently, the models can be solved for the optimal (welfare-maximizing) policies. In this paper we try to explore optimal monetary policy in a medium-scaled model for a small open economy, estimated to fit the Hungarian data (see Jakab-Világi, 2008). We do so by applying the linear-quadratic (LQ) approximation to the optimal policy problem, as suggested by Benigno-Woodford (2005), and using the standardised algorithm proposed by Altissimo et al. (2005). On top of all the usual nominal and real frictions of the applied DSGE literature, our model is a two-sector, open economy setup, with imports as an intermediate input to production. From a theoretical point of view, our contribution would be to examine how openness, and the way it is modelled, change the well-documented findings on optimal policy in the closed economy. As for practical reasons, we believe that our research can provide useful guidance to monetary policy in times when large exogenous shocks challenge on policymakers.

1.2 Scope of the paper

For a wide range of shocks, we first examine the flexible price version of the model, and explore how the economy would behave without nominal rigidities. The flexible price allocation is a natural benchmark as, by assuming away nominal rigidities, it represents the socially optimal solution of the model.[1] Then, reactions of the economy under the estimated rule are analyzed, and the role of nominal rigidities is discovered. Then we solve for the optimal policy problem, constrained by the existence of nominal rigidities. We compare the optimal policy allocation to both the flexible price model and the one with the estimated rule. By doing so, we seek to answer, on the one hand, how the optimal monetary policy succeeds in replicating the flexible price (socially optimal) allocation, and reveal, on the other hand, the major differences from an empirically motivated model. We also complete a sensitivity analysis on openness by changing the steady state share of imports in production (a proxy for openness), and compare the quasi-closed (or moderately open) versions of the model to the fully open one. In this way, we can analyze the normative consequences of increasing openness. We also show how robust our findings are to the specific features of the model.

1.3 Related literature

Our approach is similar to papers on optimal policy in "medium-scaled" closed economy DSGE (i.e. Smets-Wouters type) models of Altissimo et al (2005) and Adjemian et al. (2007). Their results suggest (and largely reinforce the findings of Clarida et al. (1999) from a much simpler setup) that in case of efficient aggregate demand shocks, the optimal monetary response is to offset, while in case of efficient aggregate supply shocks, monetary policy should seek to accommodate them. As for inefficient mark-up shocks, a trade-off between inflation and output stabilisation arises, making the monetary policy problem less clear-cut. According to Adjemian et al. (2007), facing a price mark-up shock, the monetary policy can hardly do much with inflation - at least for acceptable sacrifice in terms of real output -, therefore output stabilization becomes more important. The opposite applies, though, for inefficient wage mark-up and equity premium shocks, as in response to them and compared to estimated rule, optimal monetary policy should seek to strongly offset inflationary pressures.

Results on the open-economy properties of the optimal policy are much less abundant, more often stick to simple (as opposed to "applied") modelling setups and generally deal with the appropriate target variable ("which inflation to target?"). Clarida et al (2001) show that the optimal policy prob-

[1] More precisely, this is the case if the government subsidizes producers with monopoly power to supply the amount of output that they would in a perferctly competitive environment (case of the optimal steady state) - an assumption that we maintain throughout.

lem for the small open economy is isomorphic to the closed economy case. In particular, the small open economy dynamics can be reduced to a first order, two-equation dynamical system for domestic inflation and the output gap whose structure is identical to the one associated with the workhorse sticky price model of a closed economy. In particular, the optimal policy should seek to stabilize domestic (as opposed to CPI) inflation, and the form of the intetest rate rule is not affected by the openness of the economy. A similar result is obtained in Gali-Monacelli (2005) where strict domestic inflation targeting turns out to be the optimal monetary policy, consequently outperforming a CPI inflation targeting rule. Campolmi (2008) argues that the inclusion of sticky wages in an otherwise standard small open economy model rationalizes CPI inflation targeting. As to our knowledge, no paper is available on the welfare-maximizing policy properties of an empirically motivated, full-fledged small open economy model. Adolfson et al (2008) do a somewhat similar excercise based on the estimated DSGE model for Sweden, however, they purposely refrain from deriving the central bank objective from micro behavior, and simply assume a "sensible" loss function.

1.4 Main results

Our results suggest that by adding further channels of adjustment and more flexibility to the optimization problem, increased openness exaggerates the findings about optimal policy in the closed economy. That is, in case of aggregate demand shocks, the optimal response is still to offset, but to a larger extent than in the closed economy. Facing efficient aggregate supply shocks, monetary policy should try to accommodate them, and also, to a larger extent than in closed economy. As for inefficient price mark-up shocks, the implications are similar to those obtained in the closed economy setup in the sense that stabilising inflation would involve sizeable ("too much") sacrifice in terms of real output. Still, compared to the closed economy, optimal policy is less concerned for output stabilization. In case of wage mark-up shocks, similarly to the closed economy setup, monetary policy agressively increases the policy rate; resulting in a more volatile path for both inflation and real output. The reason behind is that, given growing real wages, strong disinflation is the only way to stabilise nominal wage inflation – and this is what the optimal policy should seek to follow.

By introducing openness, we have the opportunity to study the normative consequences of openness-specific shocks, too. We find that monetary policy should strongly offset export demand shocks, similarly to other types of efficient demand shocks. Import price hikes - imports being an input to production - act like negative shocks to the technology, and consequently, trigger a monetary restriction from the optimizing monetary authority, while an exogenous rise in the domestic interest rate premium should be strongly offset. Import being an input to production as opposed to a final consumption good dramatically changes the normative implications of a terms-of-trade shock. That is, while it is optimal for the monetary policy to look over international relative price changes in the latter setup (see Gali-Monacelli), it no longer applies once imported goods enter into production.[2]

2 The model economy

Our model is a two-sector small open economy with imports as production inputs, augmented with all the usual frictions of the applied DSGE literature (staggered price and wage setting, indexation mechanisms, adjustment costs on investment, habit formation in consumption, fixed costs in production). As the general description is available in Jakab-Világi (2008), here we just focus on the specific features that are either particularly relevant for the normative implications, or different from (that is, simplified compared to) the full model. The model equations are presented in Appendix A.

- *Production*: The production process is represented by a two-stage CES production function. In the first stage, imports and labor are combined to a composit production input, while in the second stage final output is produced out of the composite input and capital. Three characteristics of the production process are worth emphasizing. First, the elasticity of substitution is substantially lower between imports and labor, than between the composite input and capital, while the latter is also lower than unitary (that would correspond to the standard Cobb-Douglas case). Second, both the amount of capital and of the composite input is costly to adjust, so it takes time for the production inputs to respond to shocks. Third, even though the composite input as an aggregate in itself is costly to adjust, the substitution of the primary inputs for each other is not. That is, movements along the same isoquant of the composite input are costless, therefore there are strong incentives to substitute labor for imports (and vice versa) in face of any change in their relative costs.

- *Two sectors*: Production takes place in two sectors: domestic and export. The output of the former is sold at home, while that of the latter abroad. This characterisation of the production process means that the goods produced for different markets are not substitutable. Two features of the production process stand out. First, differences in the production technology amount to having different shares of imports in final output and the same productivity coefficient. Therefore, productivity shocks affect both sectors symmetrically, while shocks to import

[2] It also follows from the different setup that domestic and CPI inflation coincide in the model.

prices have a somewhat more pronounced impact on the more import-intensive sector. Second, the reaalocation of resources between sectors is, again, costless, which involves large-scale reallocation of productive resources in face of shocks changing the relative profitability of production (most importantly, terms-of-trade changes).

- *Monetary policy*: Monetary policy is characterised by a simple Taylor rule with interest rate smoothing estimated for the IT regime (from 2001). The coefficient of inflation is barely 1.4, less than the standard baseline of 1.5 (Clarida-Gali-Gertler). While this is an empirical characterisation of the Hungarian economy, it can be interpreted as a warning that the empirically motivated policy rule is possible too "dovish".

- *Rule-of-thumb consumers:* In the model used for analysing optimal policy, rule-of-thumb (non-Ricardian) consumers are assumed away. The reason is that their presence makes the problem of the social planner cumbersome (see Gali et al. (2004)), and much less operational from a central bank perspective. A general claim (see Adolfson et al. (2008)) that the approximation of household welfare is very model-dependent and aggregating utilities with heterogenous agents might be problematic. Even though Jakab - Világi (2008) found these type of agents helpful in matching the model to data, we dropped them.

- *Learning 'underlying inflation':* A special feature of the full Jakab-Világi model is that agents' *'perception on underlying inflation'* is made endogenous by a real-time adaptive-learning algorithm. As the percieved inflation term enters the price-setting mechanism (rule-of-thumb price setters partly index prices to this), this 'underlying' inflation heavily influences long-term inflation developments. In fact, the speed of learning was interpreted as a measure for monetary policy credibility (or the lack thereof). Throughout optimal monetary policy calculations, we drop the learning mechanism. The reason is that the optimal simulations assume full commitment under timeless perspective which can also be thought of having a fully credible central bank. For remaining consistent to the assumptions implicit in the approach we take, we abstract from potential problems of imperfect commitment.

The exact parametrisation of the model is described in Table 1-3 in Appendix B. Apart, from the differences highlighted above, we imported the parameters estimated by Jakab - Világi (2008) for the inflation targeting regime. Throughout the simulations, the posterior means of the parameters were chosen.

3 Optimal policy in an open economy - baseline model

In this section we explore the economy's reaction to shocks and compare the evolution of the endogenous variables under the three modelling setups: the flexible price model (FLP), the model with nominal rigidities under the estimated rule (RULE), the model with nominal rigidities under optimal monetary policy (LQ). The impulse responses of the three models to different types of shocks are presented in Appendix C. Then, we compare the policy response under the last two setups, that is the change in the policy rate induced by he shock. Next, we turn our attention to the stabilization properties of the optimal vs. the estimated monetary policy by comparing the volatilities in the "gap" variables (output gap, real exchange rate gap) and the inflation measures (domestic price and and wage inflation).[3]

3.1 General aggregate demand shock (increased government consumption)

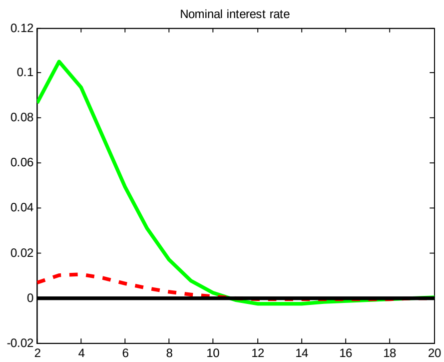
In the *flexible price model*, the usual closed-economy consequences of a lump-sum tax financed increase in government spending (decrease in consumption and rise in labour supply because of the negative wealth effect, increased output due to higher labour supply, and rise in the real interest rate because of the relative scarcity of current output) are supplemented by a strong real appreciation as the relative demand for domestic goods increases. This induces substitution effects in net exports (a substantial worsening of the trade balance) both because of the reallocation of productive resources from the export to the domestic sector, and the substitution of labour (and, to a lesser extent, of capital) for imports in both sectors. As the current account offers a way to smooth consumption, the initial drop is smaller than in a closed economy.

With *nominal rigidities* and *under the estimated rule*, the demand-side effects amplify the reaction in domestic output, leading to a positive output gap, and hence, inflation. As opposed to the flexible price open economy model, relative price movements are dampened because of price stickiness, and so are all the price-induced quantity reactions. As substitution effects play a lesser role, the worsening in net exports is less substantial, and so is the reallocation of productive resources.

The *optimal monetary policy* seeks to replicate flexible price allocation by offsetting aggregate demand pressures and stabilizing domestic inflation and aggregate output (as usual in the closed economy setup), and, additionally, "letting the relative prices play their allocational role", that is,

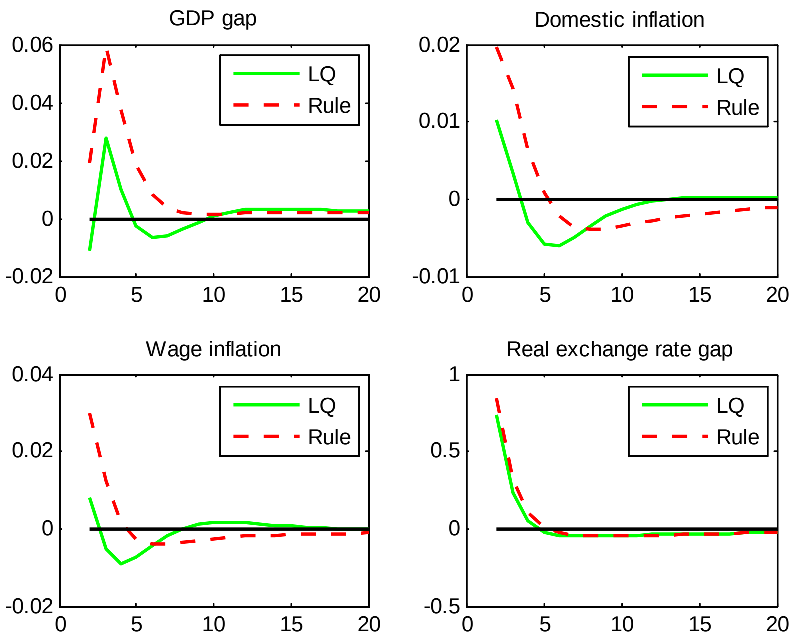
[3] Note that this is an informal excercise of "rounding up the usual suspects" as (in contrast to simpler monetary models) we couldn't get an analytical solution for the loss function. Still, the gaps and the inflation measures seem plausible to play a role.

inducing strong enough relative price movements via nominal appreciation. As nominal appreciation becomes unavoidable to bring about real appreciation, optimal policy increases the policy rate by substantially more than both the estimated rule and than in the closed economy setup.



Policy rate - increase in government spending

As for the stabilization properties of the alternative policy regimes, not surprisingly, facing an aggregate demand shock, the LQ policy is successful in stabilizing both domestic (price) and wage inflation, and is somewhat closer to the flexible price case in terms of the real appreciation (See figure 1 below.). To sum up, the closed-economy implications of optimal monetary policy remain valid in our open-economy setup, too.



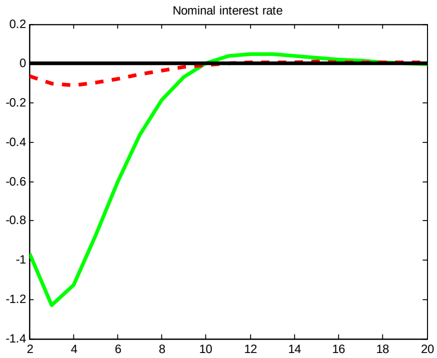
Stabilization properties of the optimal policy and the estimated rule – increase in government spending

3.2 General aggregate supply shock (improvement in technology)

In the *flexible price model*, in addition to the usual closed-economy consequences of a rise in productivity (strong positive wealth effect on households, direct growth in output, increased demand for productive inputs), the real exchange rate depreciates as relative domestic supply increases. This leads to a large "competitiveness gain" (with net exports improving), and the reallocation of all productive resources from the domestic to the export sector, and the substitution of imports for labour (and, to a lesser extent, capital) in both sectors. Consumption smoothing through current account results in a persistent consumption response.

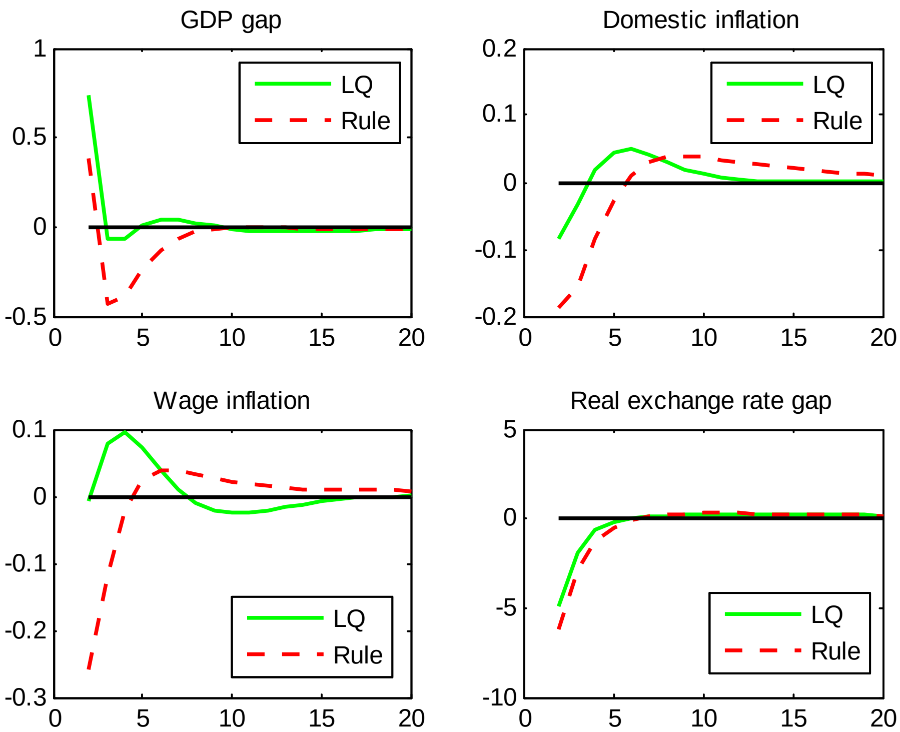
With *nominal rigidities* and *under the estimated rule*, demand-side determination of output in the short run dampens the effect of improved technology on aggregate activity. That is, as prices are largely rigid, demand for output doesn't grow enough to absorb all of the economy's productive resources: labor is partly laid off and imports decrease. Inflation decreases (turns negative) because of negative output gap effect. The adjustment is different from that in the flexible price version, as relative price movements are less important, and, consequently, so are all the price-induced quantity reactions.

The *optimal monetary policy* seeks to replicate the flexible price allocation by lowering the policy rate and this way, boosting aggregate demand (as is usual in the closed economy setup). What adds to the motivation of the central bank, is that it also seeks to induce "optimal" relative price movements (as it was the case in the flexible price model). Given nominal rigidities the way to achieve it is via nominal depreciation, which adds a further motive to the monetary loosening. Again, qualitatively, the optimal monetary reaction is the same as in the closed economy setup (lowering of the policy rate).



Policy rate - improvement in technology

The stabilization properties are similar to the case of the real demand shock scenario (much less volatility in price and wage inflation, real exchange rate closer to the flexible price evolution). The price to be paid is apparently a relatively high output volatility in the short run.

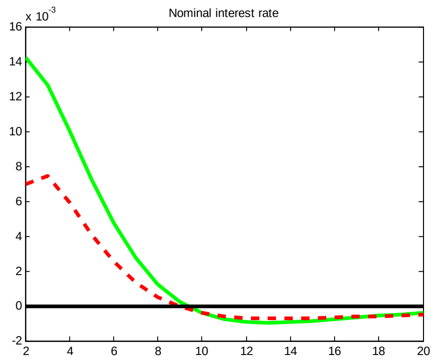


Stabilization properties of the optimal policy and the estimated rule – improvement in technology

3.3 General inefficient shock (price mark-up shock)[4]

Under the estimated rule, besides the usual closed-economy consequences of a rise in the mark-up of the monopolistically competitive domestic producers (rise in inflation, drop in output), the real exchange rate appreciates (due to both higher domestic prices and nominal appreciation following the monetary tightening). This dampens the negative impact on domestic output, as the relative increase in domestic output and factor prices attracts productive inputs to the sector.

Optimal monetary reaction is qualitatively similar, that is, restrictive. The notable quantitative difference is that the optimal policy plays more strongly on the real exchange rate appreciation by a more aggressive tightening. The more important increase in the policy rate explains the larger drop in real economic activity, the more nominal appreciation, and more subtitution between productive resources and across sectors.

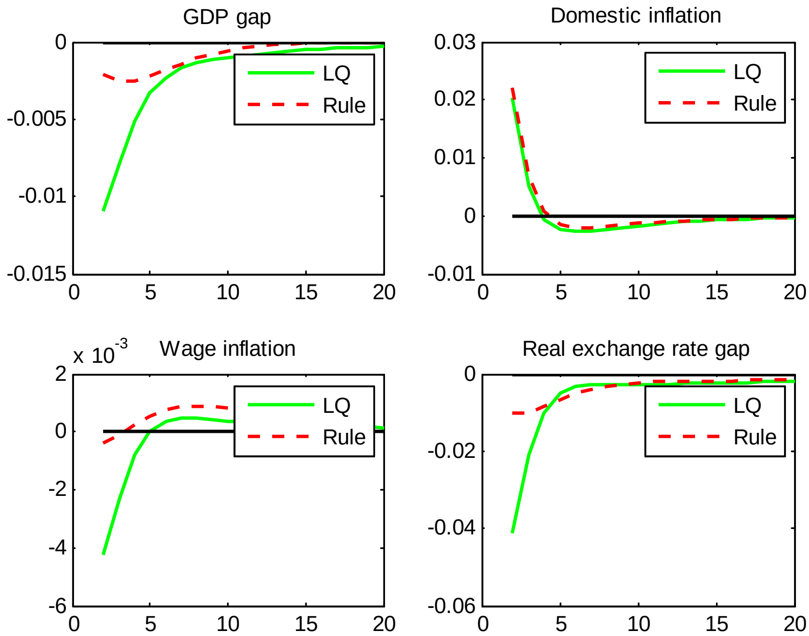


Policy rate - increase in domestic mark-up

Note that papers on optimal policy in the fully-fledged closed-economy DSGE model of the euro area (see Alitissimo et el., Adjemian et al.) find that in face of a price markup shock, the optimal monetary response is a moderate *loosening*. The intuition behind is that the monetary authority cannot really do about inflation (the mark-up shock enters directly into the pricing equation), but a lower nominal interest rate can help to dampen the adverse effects on the real activity. Here we see just the opposite, the monetary policy seems to aggrevate the loss in output, while the gain in terms of inflation stabilization is not really sizeable. This points to an interesting feature of optimal monetary policy in the open economy, namely, that it strongly tilts the trade-off between inflation and output stabilization towards the former objective.[5]

[4] As a shock to the pricing behavior of firms, the effect of an increased mark-up is interpreted only under nominal rigidities (models with explicit pricing decisions).

[5] This characteristics (that more openness makes the central bank more concerned for



Stabilization properties of the optimal policy and the estimated rule – price markup shock

3.4 Openness-specific demand shock (increase in export demand)

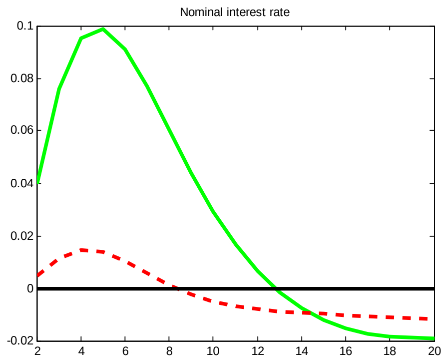
In the *flexible price model*, increased export demand acts symmetrically to any shock to domestic demand (see increase in government demand for comparison): increases relative prices of the export sector, causes a strong real appreciation and terms-of-trade improvement. Relative price movements bring about the usual channels of adjustment (reallocation of resources to the export sector, and substitution of imports for labour/capital). More real income (in terms of domestic output) leads to higher consumption, too.

With *nominal rigidities* and *under the estimated rule*, the demand-determination of output in the short run results in a stronger output and less of price reaction. The increased demand for productive resources drives up the real marginal cost and inflation. This triggers an offsetting policy response (rise in the policy rate). The adjustment is similar to the flexible price story with less of relative price adjustment, and related substitutions, but more of aggregate quantity responses.

Similarly to other efficient demand shocks (see government consumption above), *optimal monetary policy* is more restrictive than the estimated rule.

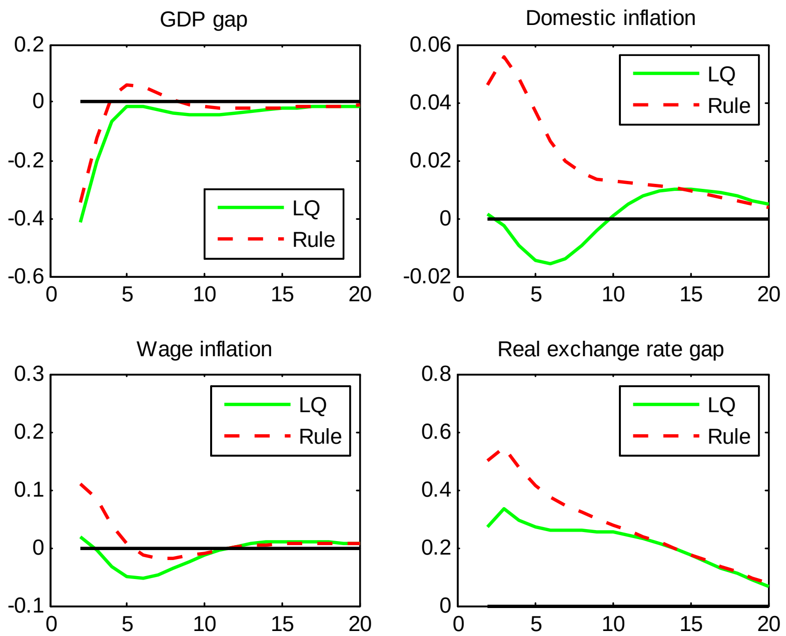
inflation) is reinforced in the next section where we compare optimal policy allocations for different degrees of openness.

The reason for this is that by directly affecting the demand side of the economy, the monetary policy can offset inflationary pressures coming from demand-side.



Policy rate - increase in export demand

As for the stabilization properties, the optimal policy is successful in mitigating the inflationary effects (both on domestic price and wage inflation), while it also seeks to replicate the real appreciation taking place in the flexible price model. Note that as monetary policy has "direct" impact on the domestic output market, while the shock is hitting another goods market (that of exports), the policy has more indirect influence on economic activity. This is the reason for the relatively less successful stabilization of the GDP gap (compared to a genuine shock to domestic demand, see government spending above).



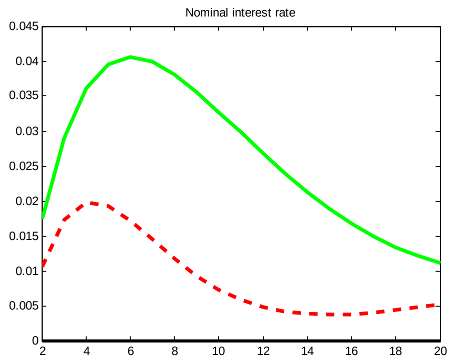
Stabilization properties of the optimal policy and the estimated rule – increase in export demand

3.5 Openness-specific supply shock (increase in import prices)

In the *flexible price model*, increased import prices act like a negative shock to technology by making production more costly and reducing output in both sectors. Obviously, the rise in import prices leads to strong substitutions in production, mostly of imports for labour. Also, the rising costs of domestic production makes the domestic firms less competitive in export markets, and induces a sectoral reallocation of inputs from the export to the domestic sector.[6]

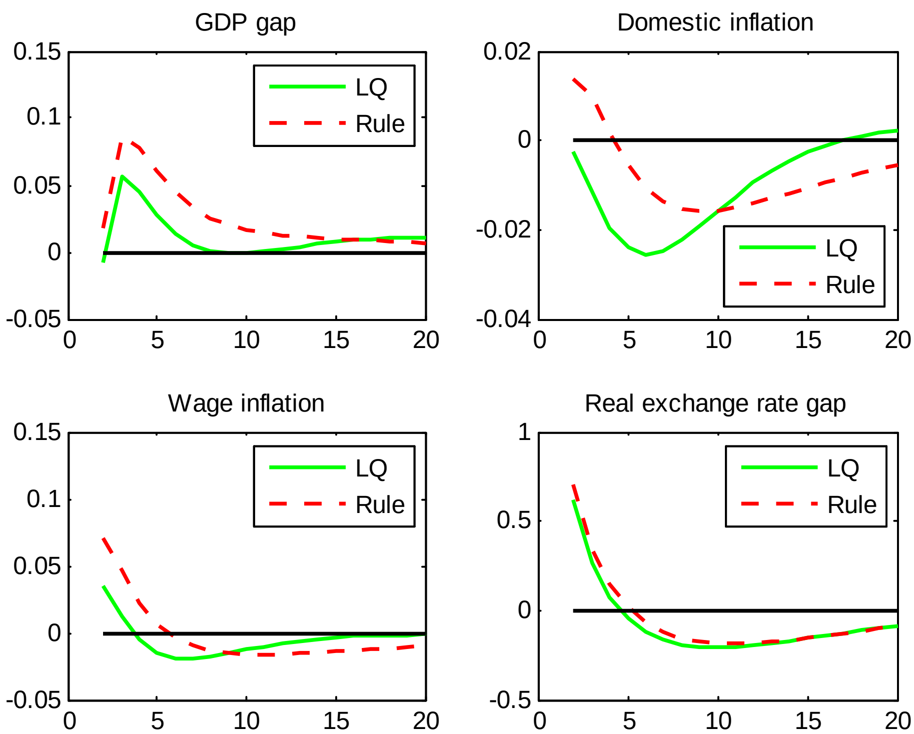
With *nominal rigidities* and *under the estimated rule*, the monetary policy reacts by a moderate tightening (symmetrically to the negative technology shock, see above). *Optimal monetary policy*, too, behaves as if facing a negative technology shock, consequently, the optimal response is a strong tightening.

[6] Note that the export sector is also somewhat more import-intensive. However, this effect is quantitatively not too important.



Policy rate - increase in import prices

The stabilization properties of the optimal policy are similar to those facing a technology shock (see above). That is, optimal policy is successful in subduing the variability of domestic and wage inflation, and inducing real exchange rate movements similar to what would prevail in the flexible price story. Again, the strong taste for disinflation implies more variation in GDP at the time of the shock (similarly to the case of the technology shock, see above).

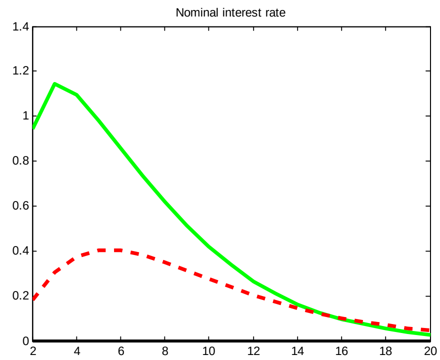


Stabilization properties of the optimal policy and the estimated rule – increase in import prices

3.6 Openness-specific inefficient shock (increase in risk premium)[7]

With *nominal rigidities* and *under the estimated rule*, the increase in the risk premium on domestic assets results in a strong nominal depreciation with all the usual substititution effects (reallocation of inputs from the domestic to the export sector, and substitution of imports for other productive resources). With the domestic price of imports going up, production costs increase, leading to inflationary pressures. In reaction to that, the policy rate is increased.

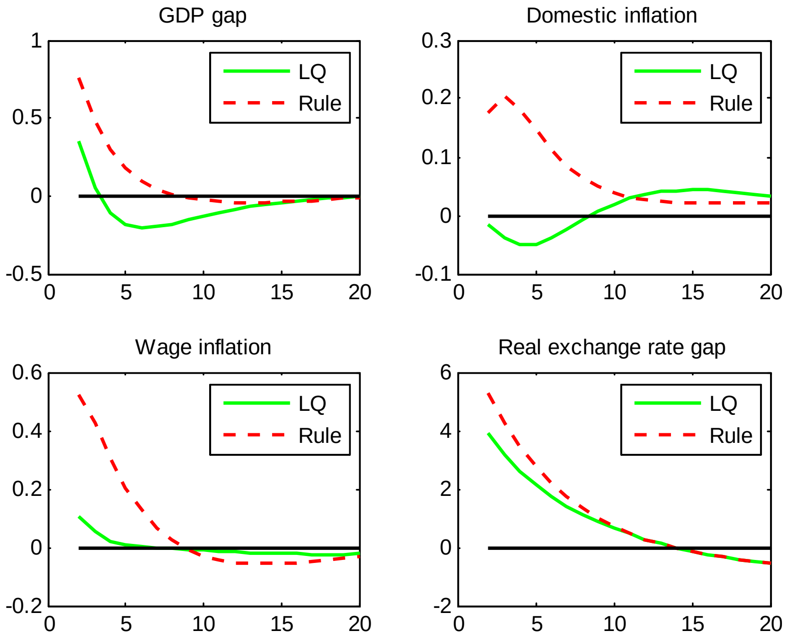
Under the *optimal policy*, the monetary policy seeks to offset the effect on inflation and on the nominal exchange rate by an aggressive tightening. Interestingly, with the baseline parameterization of the model, optimal policy is somewhat "overtightening" in the short run, as the nominal exchange rate is actually appreciating right after the shock.



Policy rate - increase in risk premium

The optimal policy is highly successful in stabilizing not only the nominal variables, but also the output gap. The reason for this is that nominal depreciation induced by the increased risk premium on domestic debt is directly offsetable by an increase of the nominal interest rate.

[7] As a shock to the nominal terms of international borrowing, the effect of an increased risk premium is interpreted only under nominal rigidities (models with explicit pricing decisions).



Stabilization properties of the optimal policy and the estimated rule – increase in risk premium

4 Sensitivity analysis: The role of openness

4.1 New channels of adjustment and heuristic implications for optimal policy in open economy

Opening up the economy offers new channels of adjustment.

First, in the two-sector open economy all shocks bring about changes in intratemporal relative prices. Movements in the terms-of-trade and the real exchange rate, then, provide incentives for reallocation of productive resources between sectors, and substitution of inputs for each other. A rise in export demand and the subsequent improvement in the terms-of-trade, would, for example, attract productive resources from the domestic to the export sector, while an exogenous increase in import prices would induce strong substitutions of imports for the less expensive inputs (labour and, to a lesser extent, capital). A second, and more renowned channel works through the current account, as international lending/borrowing offers new possibilities to smooth consumption over time. Accordingly, temporary shocks have a mitigated effect on consumption.

The new channels of adjustment have consequences on the general conduct of optimal monetary policy. The intuition behind is as follows. *New channels of adjustment provide more flexibility in terms of real adjustment.*

If real adjustment is less painful, the welfare loss associated with real (output) fluctuations becomes less important relative to fluctuations in inflation. Therefore, the inflation-output trade-off becomes tilted towards inflation stabilization. Consequently, in this model setup, by increasing the openness of the economy, the optimal monetary policy gives, ceteris paribus, higher weight on inflation and becomes less concerned about real output fluctuations.

4.2 Optimal policy in a moderately vs. a highly open economy

In this section we compare the response of the economy to shocks under different parametrization of the model. In particular, we are comparing a "moderately open" economy (in which we fix the import/output share to 20% in both sectors) to the "highly open" baseline one. The simulations - at a first glance - reinforce the intuition for the growing importance of inflation in central bank stabilization performance as the economy turns more open.

Figures to be inserted here. Text to be completed.

5 Conclusions and policy implications

We explored the properties of optimal monetary policy in an estimated, small open economy DSGE model of the Hungarian economy. The modelling framework (the two-sector setup, with imports modelled as input to production) with no adjustment costs on either sectoral reallocation of inputs, or on substitution between them, has clear normative consequences. That is, openness allows of new channels of adjustment, and, hence, increases flexibility in terms of real adjustment. Consequently, real adjustment becomes less painful, the welfare loss associated with real output fluctuations becomes relatively less important. Therefore, the inflation-output trade-off becomes tilted to inflation stabilization. In this model setup, by increasing the openness of the economy, the optimal monetary policy, ceteris paribus, tilts the inflation-output trade-off off towards inflation stabilization. A striking example of the *qualitative* difference between the closed and the open economy, is the optimal response to a price markup shock. While the closed economy implication (documented by Adjemian et al.) is that as the monetary policy "cannot do much" about inflation, and should therefore focus more on output stabilization, the opposite applies in our setup.

The policy implications from this exercise are also worth emphasizing. It stands out, that in this setup the optimal monetary response in face of a global commodity price hike is obviously a strict tightening. According to the model, this implication is even more valid in more open economies and/or with a higher share of the imported commodity in production. This result, again, is in sharp contrast with the theoretical result usually derived in the literature, i.e. terms-of-trade shocks should be overlooked Our results highlights the striking difference in normative implications that a way imports is modelled (final consumption good vs. intermediaire production input) actually makes. On the other hand, a global slowdown, represented here as a drop in external demand, calls for an opposite (as compared to rising import prices) reaction: a monetary loosening. The optimal monetary reaction to the current developments in the world economy (or put differently, the relative importance of the exogenous shocks hitting the Hungarian economy) remains to be open to fierce debate.

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Appendix A: Log-linearized model

to be completed

Appendix B: Parameters

Table 1 Fixed parameter values

Parameter		
Name		Value
standard error of gov't. consumption	σ_g	4.72
standard error of import prices	$\sigma_{p^{m*}}$	2.19
standard error of capital measurement error	σ_k	0.15
autoreg. coeff. of gov't. consumption	ρ_g	0.46
autoreg. coeff. of import prices	$\rho_{p^{m*}}$	0.74
autoreg. coeff of capital measurement error	ρ_k	0.60
autoreg. coeff of perceived average inflation	$\rho_{\bar{\pi}}$	0.99
discount factor	β	0.99
steady-state share of capital in real marginal costs, domestic	α_d	0.17
steady-state share of capital in real marginal costs, export	α_d	0.14
steady-state share of labor in w_t^z,domestic	a_d	0.50
steady-state share of labor in w_t^z, export	a_x	0.36
depreciation rate	δ	0.025
elasticity of subt. of goods	θ	6.00
elasticity of subt. of labor	θ_w	3.00
disutility parameter of labour	φ	8.00
Calvo parameter of employment	γ_n	0.70
elasticity of subt. between capital and z	ϱ	0.80
elasticity of subt. between labor and import	ϱ_z	0.50
ratio of fixed cost relative to total output	$\bar{f}_{d,}\ \bar{f}_x$	0.20
capacity utilization adj. cost	ψ	0.20
investments adjustment cost	Φ''	13.00
labour utilization adjustment cost	Φ_l''	3.00
import utilization adjustment cost	Φ_m''	3.00
exchange rate elasticity of the policy rule	ζ_e^{it}	0.025
debt elasticity of financial premium	ν	0.001

Table 2 Estimated parameters of exogenous shocks

		Prior distribution			Estimated posterior		
		Type	Mean	Stand. err.	Mode	Mean	90% prob. int.
Standard errors							
productivity	σ_A	I.Gam.	0.5	2*	2.080	2.152	$[1.82, 2.55]$
export demand	σ_x	I.Gam.	0.5	2*	2.352	2.464	$[2.06, 2.95]$
cons. pref.	σ_c	I.Gam.	0.5	2*	0.146	0.203	$[0.11, 0.33]$
cons. price markup	σ_p	I.Gam.	0.5	2*	0.397	0.420	$[0.34, 0.52]$
export price markup	σ_{px}	I.Gam.	0.5	2*	1.873	2.182	$[1.64, 2.87]$
labor market	σ_w^{it}	I.Gam.	0.5	2*	0.609	0.932	$[0.54, 1.42]$
investments	σ_I	I.Gam.	0.5	2*	0.969	1.003	$[0.76, 1.27]$
Equity premium	σ_Q	I.Gam.	0.5	2*	0.167	0.393	$[0.11, 0.99]$
policy rule	σ_r^{cr}	I.Gam.	0.5	2*	0.574	0.602	$[0.48, 0.76]$
policy rule	σ_r^{it}	I.Gam.	0.5	2*	0.229	0.247	$[0.19, 0.32]$
fin. premium	σ_{pr}^{it}	I.Gam.	0.5	2*	0.486	0.666	$[0.36, 1.06]$
employment	σ_n	I.Gam.	0.5	2*	0.369	0.383	$[0.30, 0.49]$
Autoregressive coefficients							
productivity	ρ_A	Beta	0.8	0.1	0.577	0.552	$[0.43, 0.68]$
export demand	ρ_x	Beta	0.8	0.1	0.616	0.625	$[0.51, 0.73]$
cons. pref.	ρ_c	Beta	0.8	0.1	0.833	0.767	$[0.60, 0.88]$
labor market	ρ_w^{it}	Beta	0.8	0.1	0.797	0.661	$[0.43, 0.87]$
export markup	ρ_x	Beta	0.5	0.15	0.317	0.318	$[0.15, 0.50]$
investments	ρ_I	Beta	0.8	0.1	0.497	0.488	$[0.33, 0.65]$
fin. premium	ρ_{pr}^{it}	Beta	0.8	0.1	0.872	0.820	$[0.70, 0.92]$
employment	ρ_n	Beta	0.8	0.1	0.790	0.770	$[0.64, 0.89]$

* For the Inverted Gamma function the degrees of freedom are indicated.

Table 3 Structural parameters

		Prior distribution			Estimated posterior		
		Type	Mean	Stand. err.	Mode	Mean	90% prob. int.
Utility function parameters							
consumption	σ	Norm.	2.00	0.40	1.680	1.814	$[1.18, 2.46]$
habit	h	Beta	0.75	0.15	0.597	0.646	$[0.45, 0.83]$
Price and wage setting param.							
ind. cons. prices	ϑ_p^{it}	Beta	0.60	0.20	0.416	0.431	$[0.22, 0.66]$
ind. exp. prices	ϑ_x^{it}	Beta	0.60	0.20	0.383	0.494	$[0.18, 0.83]$
ind. wages	ϑ_w^{it}	Beta	0.60	0.20	0.107	0.185	$[0.05, 0.40]$
Calvo cons. prices	γ_p^{it}	Beta	0.50	0.20	0.929	0.921	$[0.88, 0.95]$
Calvo exp. prices	γ_x^{it}	Beta	0.50	0.20	0.827	0.810	$[0.73, 0.89]$
Calvo wages	γ_w^{it}	Beta	0.50	0.20	0.711	0.657	$[0.46, 0.88]$
Other parameters							
exp. elasticity	θ_x	Beta	0.50	0.10	0.510	0.534	$[0.40, 0.67]$
exp. smooth.	h_x	Beta	0.75	0.15	0.503	0.507	$[0.35, 0.66]$
ir. smooth.	ζ_i	U(0,1)	0.50	0.29	0.766	0.761	$[0.67, 0.84]$
policy rule	ζ_π	Norm.	1.50	0.16	1.375	1.379	$[1.12, 1.65]$

Appendix B: Impulse responses

to be completed