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Empirical Determination of Aggregate Demand and Supply Curves: The Example of the RWI Business Cycle Model

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EMPIRICAL DETERMINATION OF AGGREGATE DEMAND AND SUPPLY CURVES: THE EXAMPLE OF THE RWI BUSINESS CYCLE MODEL[*]

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Summary

Modern macroeconometric models are often criticized for being too complex to be easily understood. As one way to overcome this, Hickman suggested the calculation of their implicit aggregate demand/supply (AD/AS) structure. This paper uses the theoretical IS/LM-AD/AS apparatus to analyse the simulation properties of the RWI (*Rheinisch-Westfälisches Institut für Wirtschaftsforschung*) business cycle model, a medium-sized short-term macroeconometric model for Germany. The method lends itself to comparative studies of different macroeconometric models but may also be used to understand the basic properties of a new or respecified model in theoretical terms. The present results basically confirm the theoretical expectations of AD and AS elasticities for a three-year horizon. The results also reveal particular reactions that can be linked to peculiar model specifications (such as an endogenous government sector). All in all, the results uncover model features that usually escape the standard multiplier analysis.

Keywords: AS AD, IS LM model, econometric modeling, macroeconometrics, simulation

JEL classification: C52, C53, E12, E17

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1 Introduction

Over the last 40 years, macroeconometric models have been established as major instruments of empirical research for both theoretical and policy analysis. They are especially pertinent when estimating the effects of alternative developments: e.g., of world trade or oil prices, major fiscal or monetary instruments, or changes of central parameters, such as savings ratios or mark-up factors. Discussions of the management of the present economic crisis in the U.S. (Romer, Bernstein 2009, Cogan et al. 2009) or in Germany (*Projektgruppe Gemeinschaftsdiagnose* 2009, Heilemann et al. 2008) give ample illustrations. Reception and discussion of the results, however, suffer from the fact that the models applied are unavoidably elaborate and to outsiders often appear as being overly complex or complicated. Traditional methods of simplification such as graphical, logical, and, above all, the multiplier analysis of more or less condensed versions and reduced forms are of only limited value.

In this context, Hickman (1987, 2004) suggested estimating the aggregate demand (AD) and supply curves (AS) implied by the models. This would not only shed light on a model's structure and simulation properties but also facilitate its evaluation within the framework of macroeconomic theory. The majority of macroeconometric models can be reduced to an implicit IS/LM-AD/AS core model, whose theoretical implications represent a reference system against which the central features of a model can be analyzed. Generally, the implicit curves of a macroeconometric model can be determined in two ways. The first method is using a "direct" way, deducing their reduced forms from the corresponding model equations – in essence, their analytic representations. In view of the scope and the non-linearity of most macroeconometric models, this is rather difficult (Visco 1991). A simpler alternative is the simulation approach, which provides "indirect" quantitative and qualitative results regarding model elasticities. Despite these advantages, this method has rarely been employed.[1]

Here, we use Hickman's approach to determine the implicit AD and AS functions of a macroeconometric model for Germany. Section 2 presents the methodological approach applied to the short-term effects of supply- and demand-side impulses in a simple IS/LM-AD/AS model framework. Section 3 describes the model to be used, the RWI business cycle model, as well as the simulations to be made. Section 4 reports the elasticities of the model curves and a number of simulation results that support their evaluation. Furthermore, the estimated AD and AS curves are compared to results of similar models for the U.S. and of European multi-country models. Section 5 ends with a brief summary and conclusions.

[1] See the references in Hickman 2004 and in Whitley 1992.

2 Estimating the curves of a macroeconometric model

The discussion of the short-term effects of exogenous disturbances in macroeconomic theory usually takes place within an IS/LM-AD/AS framework, whose characteristic structures are also to be found in the majority of macroeconometric models: on the demand side, in the form of a disaggregated explanation of aggregate demand and a more or less aggregated explanation of monetary quantities and interest rates. Typical for the supply side of these models are a modified Phillips approach determining wages and a mark-up approach explaining prices. The results of standard economic policy impulses can thus be used to compute the implicit IS, LM, AD, and AS curves of macroeconometric models.[2] In this paper we restrict the analysis to adjustment processes resulting from exogenous impulses leading an economy from an old to new short-term "equilibrium" (Hickman 2004).

2.1 Demand-side impulses

Figure 1 shows the typical textbook figure of a fiscal policy impulse illustrating the stylized reactions of an IS/LM-AD/AS model core. Assuming log-linear relations, the slopes of the curves express their elasticities. Following an expansionary impulse (e.g., increasing government spending), the IS and AD curves are shifted rightwards. If the LM curve remained unaffected, its slope could be calculated from a comparison of the old (A) and new (B) equilibrium values for real income and the nominal interest rate. Since the price level increases along the AS curve, however, the LM curve is shifted upwards (LM1), as the real money stock falls. Increasing prices also influence IS1, although the empirical effects are uncertain, according to previous model studies (Hickman 1987, Green et al. 1991).

On one hand, employment may not immediately increase to the same extent as output (labour dishoarding), so labour productivity increases, and hence unit labour cost decreases. Consequently, the pressure on prices is limited, at least in the short term, and real wages, disposable income, and real private consumption will rise. On the other hand, a price level increase reduces real wealth ("Pigou effect") so that negative effects on aggregate demand are also conceivable. Thus, the impact on IS1 induced by the alterations of the price level depends on the special properties of the underlying model: i.e., its behavioural hypothesis and parameters. In Figure 1 (left panel), it is assumed that the "real wage effect" is dominant (IS2) and outweighs the upshift of the LM curve.

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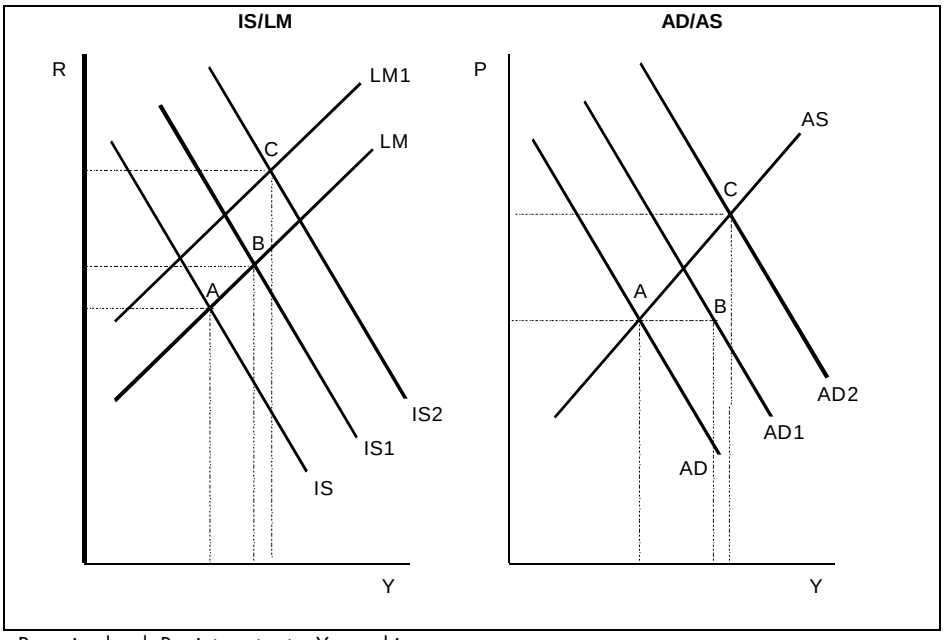
[2] The following discussion abstracts from expectations and foreign trade relationships. For other accounts, see Hickman 1988, p. 92.

Figure 1: Demand-side impulse (increasing government spending)



P – price level, R – interest rate, Y – real income.

Obviously, a comparison of equilibria A and C (Figure 1, left panel) generates too low an elasticity of the LM curve. In order to calculate unbiased elasticities, the effects of prices have to be isolated. Theoretically, this could be achieved by assuming a horizontal AS curve. Practically, in simulations with macroeconometric models this could be done by holding the AS model block (e.g., wage rates, prices, employment, …) constant. Corresponding computations by the authors indicate, however, that such price-induced distortions are of minor importance in evaluating the properties of the RWI model, at least in the short term, since its wage and price equations respond slowly to demand side impulses. It was thus decided to report only the results of complete model simulations in this paper. [3]

In a similar fashion, we calculated the IS elasticities with respect to an expansionary monetary policy impulse: i.e., a rightwards shift of the LM and AD curves (not shown here). Comparing the old and the new equilibria results in a slightly (upwards) biased elasticity for the IS curve because of further adjustment processes linked to the price changes mentioned. Furthermore, the results for the demand-side impulses can also be used to estimate the AS elasticities between A and C (Figure 1, right panel).[4]

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[3] For the computation of elasticities using partial simulations, i.e., the solution of isolated model blocks, see, e.g., Green et al. 1991. Partial simulations have the advantage of producing the lowest level of bias when calculating the elasticities, but "if the interdependences among the locuses are neglected, misleading inferences may be drawn about the response patterns of the model(s) as a whole" (ibid., p. 123).

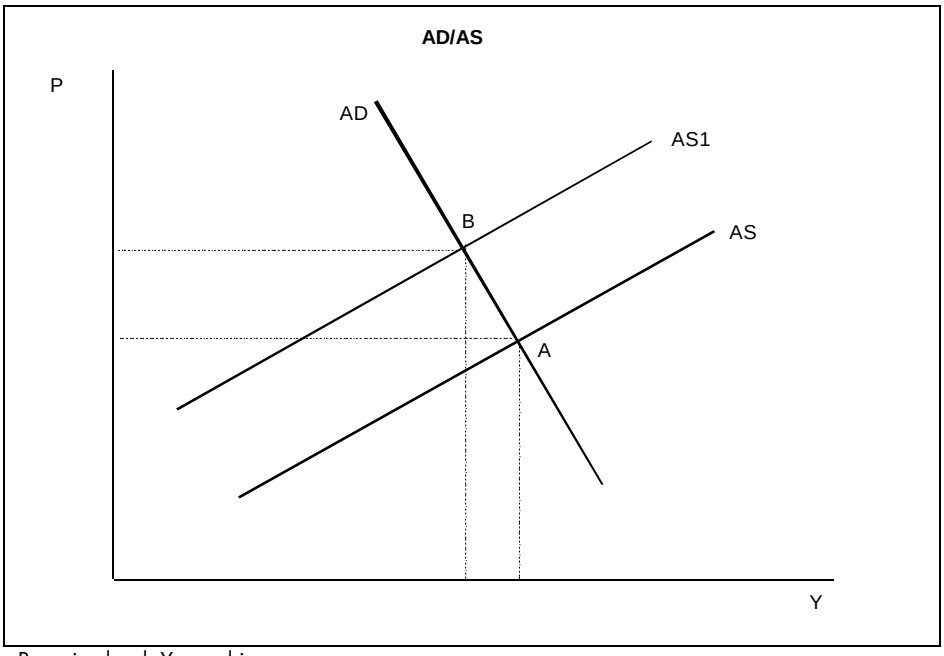
[4] AS elasticities are also biased if interdependencies between the AS and AD curves emerge. For possible causes, see Hickman 1987 and Green et al. 1991.

2.2 Supply-side impulse

The estimation of the implicit AD elasticity proceeds in a similar way. An increase in wage rates, for example, shifts the short-term supply curve upwards (AS1), since wages influence the macroeconomic price level as a cost factor (mark-up approach). Movements along the original demand curve increase the price level and cause a fall in real income. The elasticity of the AD curve can be calculated by comparing the short-term equilibrium values for real income and price level at points A and B under the assumption that AD is not affected by the supply-side impulse (see Figure 2).

After all, it is possible that, for example, a permanent redistribution in favour of labour affects the behaviour of consumers and firms (a change in relative prices). Lagged price adjustments may temporarily increase real disposable income and consumer demand: i.e., the AD curve could be shifted rightwards (not shown here). On the other hand, increased wages may have cost-induced effects on employment and investment. Again, these compensatory effects depend on the structural properties of the macroeconometric model employed. In order to limit a possible bias, we only report the results of a three-year simulation horizon in this paper. Nevertheless, the distortion from interdependencies between AS and AD curves should be small (Hickman 1987), especially as the results of sensitivity analyses of macroeconometric models suggest relatively small interdependencies between the various model blocks (Kuh, Neese, Hollinger 1985, Heilemann, Münch 1992).

Figure 2: Supply-side impulse (increasing wages)



P – price level, Y – real income.

2.3 Simulation approach

Basically, our approach consists of a set of macroeconometric model simulations. Starting point is a non-linear, dynamic model expressed in the following simplified notation: [5]

$$f\left(y_t, y_{t-1}, x_t, \beta\right) = u_t, \qquad (1)$$

where f is a vector of G functional relationships, y_t is a vector of G current endogenous variables, y_{t-1} is a vector of G endogenous variables lagged one period, x_t is a vector of K current exogenous variables, β is a vector of J constant coefficients, and u_t is a vector of G additive error terms. A deterministic simulation ($u_t \equiv 0$) of this system solves for the current values of the endogenous variables, conditional on the initial values of the lagged endogenous variables, on the values of the exogenous variables, and on the model's coefficients.

Standard multiplier (or reduced form) analysis typically studies the effects of changes of exogenous variables, i.e., $\delta y_t / \delta x_t$. Here, the outcome of such experiments is analyzed with a focus on the effects of changes of endogenous variables, i.e., $\delta y_{it} / \delta y_{jt}$ (i, j=1, …, G, i≠j), which can be interpreted as the

[5] Note that (1) contains neither lagged exogenous nor higher-order lagged endogenous variables, which can be thought of as being eliminated by introducing additional endogenous variable definitions included in the G equations of the model.

structural relationships of a system. In short, specific simulation exercises are performed (see Section 3.2), and subsequently the model elasticities ε_{ij} of time t (t=1, 2, …, T) are calculated as the percentage differences of the endogenous variables i and j between the associated baseline (b) and distorted solutions (s):

$$\varepsilon_{ij}^{t} = \frac{y_{it}^{s} - y_{it}^{b}}{y_{jt}^{s} - y_{jt}^{b}} \times \frac{y_{jt}^{b}}{y_{it}^{b}} \qquad (2)$$

While it is also possible to broaden the study of the model curves with respect to model dynamics – i.e., $\delta y_t / \delta y_{t-1}$, and parameter sensitivity, i.e., $\delta y_t / \delta \beta$ – we have leave this to future research.

3 Model and scenario design

3.1 RWI business cycle model

In order to describe the effectiveness of the approach outlined, we will employ the RWI business cycle model, a medium-sized quarterly macroeconometric model that has been used for forecasting and economic policy analysis for more than 30 years (Heilemann 2004). It is an interdependent, weakly non-linear system of equations; the version used (61[6]) consists of 136 equations (45 stochastic equations and 91 definitions). It can be subdivided into five main blocks: the explanation of demand (10, 24), prices (8, 10), distribution (6, 16), origin (5, 23), and the government sector (16, 18). The most important exogenous quantities are internationally determined variables (world trade volume and price index of imports) and economic policy variables (public investment in construction, the average contribution rate to social security schemes, and short-term interest rate). The model may be labeled as "eclectic," as it comprises neoclassical features as well as Keynesian and monetarist elements. Its overall construction is of the Keynes/Klein type; i.e., it is – as with every short-term analysis – demand-oriented and thus contains a well-developed multiplier-accelerator relationship, whilst monetary factors play only a secondary role.

The structural parameters of the model are estimated using the least squares method. The sample period forms a 40-quarter moving window, and the sample period of the version used here covers the period from the first quarter of 1995 to the fourth quarter of 2004. The solution of the model's simultaneous block is performed using the Gauss-Seidel algorithm. Despite several non-linear specifications (e.g., of behavioural equations, ratios, and quotas) the RWI model displays almost linear reactions. Therefore,

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[6] Version 61 from March 2005 was slightly modified and re-estimated. The model used and all results are available from the authors upon request.

only deterministic simulations are carried out here. The explanatory and projection quality of the model is equivalent to that of other models and the *Projektgruppe Gemeinschaftsdiagnose* of the leading German economic research institutes.

3.2 Simulation design

The fiscal policy impulse consists of a permanent increase of governmental construction outlays by one billion euros per quarter (Simulation I). For diagnostic reasons, the simulation is repeated with an exogenous government sector.[7] As to monetary policy, it is assumed that the central bank holds the short-term nominal interest rates constant: i.e., it proceeds from the assumption of an accommodating monetary policy.[8]

First, the monetary impulse is simulated via a reduction of short-term nominal interest rates by 100 basis points (Simulation II) because this variable is exogenous in the present model version. The setting of the interest rate implies a horizontal LM curve.[9] Alternatively, in another diagnostic simulation, we examined which elasticities result for the IS, LM, and AS curves when money stock is taken into consideration as an explicit instrument of monetary policy and thus an endogenous determination of the interest rate as with the IS/LM model (Simulations IIa & IIb).

The supply-side impulse consists of a permanent increase of the annual rate of change of negotiated wages and salaries (subsequently referred to as wages) by one percentage point (Simulation III). In order to keep the employment-wage-price mechanism of the model, the impulse is implemented into the wage equation via add-factoring. Additionally, the same diagnostic simulations as with demand-side impulses are performed (exogenous government sector, endogenous short-term nominal interest rates).

4 Results

4.1 IS and LM curves

Table 1 shows the results of the simulations of the two demand-side impulses for the variables of the IS/LM-AD/AS model as percentage differences from the baseline solution for three years.

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[7] Since exogenization alters the structure of a model, the results of this exercise have to be interpreted carefully. In addition, the consistency of the exogenous variables with respect to national accounts is not ensured for the associated simulations; however, this is a general problem of changing exogenous variables in a model context.

[8] To what extent this assumption is realistic in view of a common European monetary policy remains to be seen; it applies more to the "contractionary" case than the "expansionary" case.

[9] For an alternative interpretation of the interest rate setting in a Keynesian macro model without an LM curve, see Romer (2000).

Table 1: Effects of demand-side impulses on selected variables (Simulations I & II)
Percentage differences from baseline and elasticities

Year	Y	P	i	ε_{LM} [c]	ε_{IS} [c]	ε_{AS} [d]	W	Y/N
	% Differences			Elasticities			% Differences	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Simulation I: increasing governmental construction outlays [a]							
1st	0.2	0.0	0.0	infinite	-	13.4	0.0	0.1
2nd	0.3	0.1	0.0	infinite	-	3.3	0.1	0.0
3rd	0.3	0.2	0.0	infinite	-	1.6	0.1	-0.0
	Simulation II: decreasing short-term nominal interest rates [b]							
1st	0.0	-0.0	-22.1	infinite	-0.0	-72.7	0.0	0.0
2nd	0.0	0.0	-30.3	infinite	-0.0	11.1	0.0	0.0
3rd	0.0	0.0	-30.1	infinite	-0.0	2.7	0.1	-0.0

Authors' computations. Y – real GDP, P – GDP price deflator, i – short-term nominal interest rate, W – nominal wage rate, Y/N – labour productivity. a) A permanent increase of one billion euros per quarter with constant short-term nominal interest rates. b) A permanent decrease of 100 basis points. c) $\varepsilon_{LM,\ IS}$ = (1)/(3). d) ε_{AS} = (1)/(2).

They indicate a horizontal LM curve (as assumed with Simulation I and II) and a highly inelastic IS curve (Simulation II). A possible bias induced by alterations in the price level is kept within strict limits in view of relatively low price reactions (column 2); this points to rather robust elasticities. The slope of the IS curve remains remarkably stable. The steep IS and flat LM curves mean a substantial income response of fiscal stimulus relative to monetary policy impulses for both accommodating and non-accommodating (not shown here) monetary policy.

4.2 Aggregate supply curves

The estimates of the AS curve (Table 1, column 6) point to a very elastic aggregate supply, suggesting that demand-side impulses stimulate growth and employment (Table A2). Furthermore, price effects are very small, so the differences of the AS elasticities between the demand impulses are partly due to rounding. The reason for the change over time is the lag structure of the corresponding price and wage equations, as the model curves shift due to their dynamic adaptation to the impulses over the course of time. Particularly noticeable are the negative price changes in simulation II for the first year. This contradicts the theoretical expectations of the AD/AS model.

The following decomposition of the response of prices to output enables a more detailed structural

analysis.[10] Using dot notation for the percentage changes of the model's supply-side variables, specifically the GDP price deflator ($\dot{P}$), nominal wage rate ($\dot{W}$), rate of unemployment ($\dot{U}$), and real GDP ($\dot{Y}$), whilst accounting for unit labour cost ($\dot{ULC}$), the inverse elasticity of the AS curve is (Whitley 1992):

$$\dot{P}/\dot{Y} = \dot{P}/\dot{ULC} \times \dot{ULC}/\dot{W} \times \dot{W}/\dot{U} \times \dot{U}/\dot{Y} . \qquad (3)$$

Within the framework of the AD/AS model (Section 2), the expected signs of these elasticities are:

$$\dot{P}/\dot{ULC}, \dot{ULC}/\dot{W} > 0 \text{ and}$$

$$\dot{W}/\dot{U}, \dot{U}/\dot{Y} < 0 ,$$

so that the slope of the AS curve is positive. Table 2 shows that the negative AS elasticity of the first year results from a particular (although by no means rare in models of the Keynes/Klein type)[11] feature of the RWI business cycle model: Despite increasing wages following expansionary fiscal and monetary impulses, unit labour costs sink in the first year due to procyclical productivity effects[12] (Table 1, column 8), so that (slowly) rising wages and falling unemployment do not put pressure on prices. Moreover, the slight fall in the price level within the first year generates an additional stimulus to real wages and demand, particularly to private consumption. Increased unit labour costs produce positive price effects only from the second year on and, as a result, dampen demand for goods and subsequently labour.

Surprisingly, the AS elasticities of simulation I in the first year, initially calculated with the "correct" sign, are only the result of the negativity of all four partial elasticities. Yet in view of their calculation and the associated model equations, the negative relationship between unit labour cost and prices (column 1) is explicable. The price determination of demand aggregates follows a mark-up approach, which was partially extended during the investment price equations by a "demand-pull" factor (capacity utilization). In doing so, falling unit labour costs are compensated for by demand-induced price increases in comparison to simulation II. Moreover, it becomes clear that the various AS curve elasticities of the complete model subject to the demand-side impulses can mainly be attributed to the partial elasticities of prices with respect to wages (columns 1, 2 and 6): i.e., the respective price equations. In other words, the differences are due to the different ways the two demand-side impulses propagate through the price sector of the model.

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[10] An interpretation of the scale of the elasticities makes sense only in comparison with that of other models.

[11] See Duggal, Klein, McCarthy 1974, Hickman 1987 and Green et al. 1991.

[12] A reason for the increasing (labour) productivity is to be found in the lag of employment creation. In the behavioural equation of employees the mean-lag makes up seven quarters. This means that it takes just under two years before half of the effect of a (single) demand impulse is processed.

Table 2: Decomposition of AS elasticities (Simulations I & II)

Year	$\dot{P}/\dot{ULC}$	$\dot{ULC}/\dot{W}$	$\dot{W}/\dot{U}$	$\dot{U}/\dot{Y}$	$\dot{P}/\dot{Y}$ c)	$\dot{P}/\dot{W}$ d)
	Elasticities					
	(1)	(2)	(3)	(4)	(5)	(6)
	*Simulation I: increasing governmental construction outlays*a)					
1st	-0.3	-9.0	-0.2	-0.2	0.1	2.5
2nd	0.7	2.2	-0.4	-0.5	0.3	1.5
3rd	0.8	1.5	-1.1	-0.5	0.6	1.1
	*Simulation II: decreasing short-term interest rates*b)					
1st	0.0	-14.4	-0.2	-0.2	-0.0	-0.6
2nd	1.3	0.7	-0.3	-0.3	0.1	0.9
3rd	0.6	1.7	-0.7	-0.5	0.4	1.0

Authors' computations. P – GDP price deflator, ULC – unit labour costs, W – nominal wage rate, U – unemployment rate (in absolute changes), Y – real GDP. a) A permanent increase of one billion euros per quarter with constant short-term real interest rates. b) A permanent decrease of one percentage point. c) $\dot{P}/\dot{Y}$ = (1)*(2)*(3)*(4). d) $\dot{P}/\dot{W}$ = (1)*(2).

4.3 Aggregate demand curves

Computation of the AD elasticities is based on the supply-side scenario: i.e., on the impact of higher wages on real income and prices (Table 3). The results indicate an extremely inelastic and positively sloped AD curve for the first two years. The price level reacts according to theoretical expectations, but real GDP also increases initially. In absolute terms, the increase of macroeconomic demand in the first year is solely due to real private consumption expenditure because higher disposable income offsets the negative effects of increasing unit labour costs on real fixed business investment and employment (Table A2). After the second year, real macroeconomic demand declines, as increasing labour costs and prices put pressure on both investment and consumption. Additionally, the increase in unemployment reduces the level of disposable income, thus reducing the initial growth in purchasing power brought about by an increase in wages.[13]

[13] See Heilemann, Ulrich 2007, where the effects of a reduction in negotiated wages and salaries (limited to four quarters) on employment creation are also very low in the first year.

Table 3: Effects of supply-side impulse on real income, price level, and interest rate (Simulation III) Percentage differences from baseline and elasticities

Year	Y	P	i	ε_{AD} [b]	$\dot{P}/\dot{W}$	$\dot{Y}/\dot{W}$
	% Differences			Elasticities		
	(1)	(2)	(3)	(4)	(5)	(6)
	Simulation III: Increasing annual rate of change of negotiated wages and salaries[a]					
1st	0.0	0.3	0.0	0.1	0.3	0.0
2nd	0.0	0.8	0.0	0.0	0.4	0.0
3rd	-0.1	1.4	0.0	-0.0	0.5	-0.0

Authors' computations. Y – real GDP, P – GDP price deflator, i – short-term nominal interest rate, W – nominal wage rate. a) A permanent increase by one percentage point with constant short-term nominal interest rates. b) ε_{AD} = (1)/(2).

In a similar way as has been used to determine the AS curve, the relationships among wages, prices, and real income can be studied by comparing the percentage changes of the nominal wage rate ($\dot{W}$), GDP price deflator ($\dot{P}$), and real GDP ($\dot{Y}$):

$$\dot{Y}/\dot{W} = \dot{Y}/\dot{P} \times \dot{P}/\dot{W} . \qquad (4)$$

The first factor corresponds to the AD curve, and the second represents the proportional extent of the upwards shift exhibited by the AS curve following a wage impulse. The elasticities in Table 3 make it clear that wage changes have significant effects on the macroeconomic price level (column 5). In contrast, the reactions of real income to the wage impulse are relatively small in the first two years (column 6). The positive sign of the AD elasticity results from the short-term stimulating effects of higher wages on real macroeconomic demand (private consumption). From the third year onwards, rising unemployment reverses the overall effect so that the elasticity of the AD curve displays the expected sign (column 4).[14]

[14] Based on the usual assumption that the AD curve displays a negative slope. Nevertheless, the elasticities also depend on the magnitudes of the opposing income and substitution effects resulting from policy measures over the course of time. For the present case, the income effect tends to dominate the substitution effect of increasing wages in the first year because employment starts to decrease only after three quarters.

Table 4: Results for complete model simulations and diagnostic simulations

Elasticities		1st year	2nd year	3rd year
Full model	AD	0.1	0.0	-0.0
	AS[a)]	13.4	3.3	1.6
	IS	-0.0	-0.0	-0.0
	LM	infinite	infinite	infinite
Model with exogenous government	AD	0.6	0.4	0.3
	AS[a)]	21.9	6.0	2.9
	IS	-0.0	-0.0	-0.0
	LM	infinite	infinite	infinite
Model with endogenous interest rate	AD	0.1	0.0	-0.0
	AS[a)]	13.4	3.3	1.6
	IS	-0.0	-0.0	-0.0
	LM	0.3	0.1	0.1

Authors' computation. a) Results of the fiscal policy impulse (Simulation I).

The highly inelastic AD curve is consistent with the results from a comparative study for the U.S. of the "macroeconomic impacts of energy shocks" (Hickman, Huntington, Sweeney (eds.) 1987). This study showed that models with relatively steep IS and flat LM curves, so-called fiscalist models, display a tendency towards producing steep AD curves. One of the reasons put forward to account for this trend is that changes in the price level with a given nominal money stock have relatively minor effects on real output in models with a low interest rate elasticity of macroeconomic demand: i.e., with a steep IS curve.

Table 4 shows the complete model results and diagnostic simulation results. In the case of an exogenous government sector, the IS and LM elasticities remain the same, whereas the AD and AS curves become considerably flatter. For a given AS curve, demand impulses would be even more effective with respect to output and unemployment. Surprisingly, the elasticity of AD becomes markedly positive: The wage impulse is more expansionary with an exogenous government sector, as otherwise higher income taxes and social security contributions limit the increase of net wages and salaries and, hence, of disposable income as well as private consumption. These results indicate that the model's "automatic stabilizers" correct the expansionary effects of demand and supply-side impulses mainly through a skimming of purchasing power. Thus, the endogenous determination of the government sector has considerable

repercussions for the properties of the model and, with it, the elasticity of the AD curve.

An endogenous determination of the short-term nominal interest rate[15] has only limited influence on the model reactions (Table A1). There are no obvious differences in the effects on income or price level, which indicates that the model elasticities to the modification undertaken are relatively robust, as interest rate effects on other model variables remain small and occur only with delay. At the same time, the interest rate equation (footnote 15) can be viewed as a reduced form of the implicit LM curve: A permanent increase in real GDP of one percent increases interest rates *ceteris paribus* by some 15 basis points in the first year, by 28 basis points in the second year, and by 23 basis points in the third year.[16] This implies an average LM curve elasticity of 0.3 in the first year and 0.1 in the two following years, which corresponds to the diagnostic simulation findings (Table 4).

4.4 Evaluation and comparison

As is to be expected in a model of the Keynes/Klein type (and in short-term analysis in general), the demand side plays a dominant role (see also Figure 3). Minimal and delayed[17] price reactions strengthen the real effects of fiscal policy. In contrast, the effects of monetary policy on, for example, employment and output – as underlined by the IS and LM elasticities – are comparatively small, as private demand appears to be relatively insensitive to changes in interest rates (Simulation II) or money stock (Simulation IIb). However, the calculated elasticities for a wage impulse present a relatively minor real effect but relatively strong reactions from the price level, which reflects inelastic macroeconomic demand.

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[15] Based on an inverse liquidity preference function of the IS/LM model, the following equation was estimated for quarterly data from 1995I to 2004IV and introduced into the model:

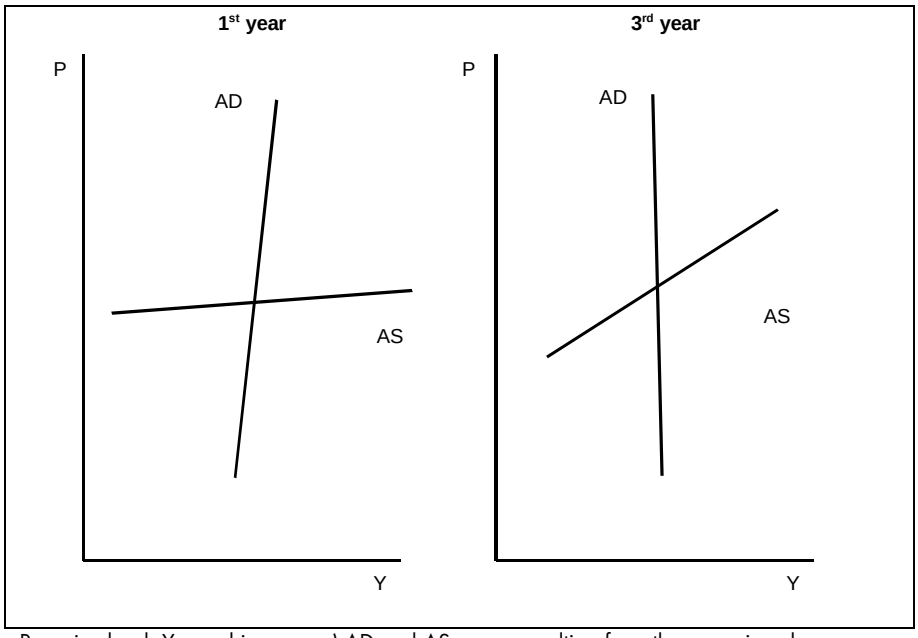
ZINSK = -26.4 + 6.33*log(BIPR) – 1.87*log(M1/PBIP*100) + 0.94*ZINSK(-1) – 0.24* ZINSK (-4)
(2.76) (3.19) (3.68) (13.80) (3.86)

R^2 = 0.92; F-value = 110.1; SER = 0.24.
with ZINSK: short-term nominal interest rate; BIPR: real GDP; M1: money stock M1; PBIP: GDP price deflator.
In (…): t-values; SER: standard error of regression.

[16] Annual elasticities are computed from the quarterly results.

[17] For example, the mean-lag in the equation explaining prices of private consumption is about seven quarters.

Figure 3: AD and AS curves of the RWI business cycle model[a)]



P – price level, Y – real income. a) AD and AS curves resulting from the wage impulse (Simulation III) and the fiscal policy impulse (Simulation I), respectively.

In order to compare the elasticities, the RWI business cycle model is contrasted to corresponding results from two comparative studies: first, of 14 U.S. models and, second, of five European multi-country models and its German parts, respectively.[18] For reasons of clarity, this paper only presents the average model elasticities of the AS and AD curves.

The AD elasticities of the RWI business cycle model and the multi-country models show a considerable degree of congruence, both in terms of the scale and the change to the mathematical sign over time (Table 5, columns 1-3). In contrast, the U.S. models present an average aggregate demand curve with a considerably flatter progression. One explanation for this difference is the significance of the government sector or the "automatic stabilizers" (mentioned above) for the responsiveness of macroeconomic demand in the German economy (see also, e.g., OECD 2009, pp. 117 f.).

[18] For the models and their sample periods, see the notes in Hickman, Huntington, Sweeney (eds.) 1987 and Whitley 1992. For more recent information about some of the European multi-country models, see Wallis 2004. Unfortunately, the presented results of the latter are not easily comparable because of different simulation experiments and data presentation.

Table 5: Elasticities of AD and AS curves of several macroeconometric models

	ε_{AD}			ε_{AS}		
	1st year	2nd year	3rd year	1st year	2nd year	3rd year
	(1)	(2)	(3)	(4)	(5)	(6)
Hickman (1987)[a)]	-	-1.3	-	-	33.7	-
Whitley (1992)[b)]	0.1	-	-0.1	15.8	-	0.9
RWI[c)]	0.1	0.0	-0.0	13.4	3.3	1.6

Authors' computations. For sources see text. a) ε_{AD}: Increase in the world oil price of 50 percent. ε_{AS}: A 10 percent reduction in income tax. b) ε_{AD}: Increase in wages per employee of one percent. ε_{AS}: Increase in real government consumption expenditure of one percent of real GDP. c) ε_{AD}: Increase in the annual rate of change of negotiated wages and salaries of one percentage point. ε_{AS}: Increase in government construction outlays of one billion euros.

The elasticities of the AS curve are also similar to the average of the European multi-country models, whilst there is again some degree of difference from the U.S. models (Table 5, columns 4-6). Particularly striking is the extreme elasticity implied by the latter for the second year.[19] This relatively high degree of elasticity is obviously the result of greatly delayed price effects and pronounced productivity effects, which give added stimulus to macroeconomic demand, thus serving to delay adaption to the new equilibrium.[20]

5 Summary and conclusions

The credibility of a macroeconometric model is dependent not only from its statistical characteristics and performance but also from the consistency of its basic properties with macro theory (so, of course, the story may go also *vice versa*). The demand side of these systems consists largely of a disaggregated IS/LM model core and the supply side of imperfect labour and product markets. As a result, their features can be expressed in terms of an IS/LM-AD/AS model framework. "Estimation of the elasticities of the IS and LM curves provides a useful diagnostic tool for characterizing the responses to fiscal and monetary policies in a given model, and it may direct attention to specific equations or parameters in

[19] Another particularity of the RWI model compared with other models is its negatively sloped short-term AS curve with respect to monetary policy impulse in the first year (Table 1). Similar results, however, are also found in a number of U.S. models, for example, by the Michigan Annual Econometric Model (-56.1) and the Hubbard-Fry Model (-13.9). See Hickman 1987, p. 147.

[20] A more detailed analysis should take into account the different sample periods, structures, and explanatory goals of the models. A case in point is multi-country models and increasing international, in particular European, integration. See, e.g., Dalsgaard, André, Richardson 2001 and Whitley 1992.

either sector in need of further testing" (Hickman 2004, p. 274). At the same time, this approach also helps to reduce the complexity of models by expressing their basic reactions in well known and easy-to-compare terms.

This paper followed Hickmans approach to analyse the RWI business cycle model, a medium-sized quarterly macroeconometric model of the Keynes/Klein-type employed for forecasting and policy analyses for the German economy for more than 30 years. The results – i.e., the computed elasticities of the model – are principally matching expectations from macro theory but also reveal two peculiarities: in the first year of simulation, first, a negative price/unit labour cost relationship following a demand-side impulse; and second, a short-term dominance of the income effect following a wage impulse. As to employment, cost effects dominate income effects only after three quarters. In diagnostic simulations, AS and AD elasticities show considerable differences when the (endogenous) government sector is exogenized. Due to small and lagged price effects of demand-side impulses in the first three years, we presented the results of complete model simulations. To check the stability of the model results, complete model simulations have to be modified to make sure that the high tax creep of the German tax system (which is corrected for these effects about every five years) does not produce massive fiscal surplus and thus does not hamper economic growth. These results would also help to determine implicit long-run curves of the model, although this is not a main focus of a short-term model.

IS/LM-AD/AS curves proved to be helpful empirical benchmarks to assess a model's structure and reactions. It may also be used for policy evaluations, e.g., to visualize the effects of different tax rates or structural changes (direct vs. indirect taxes) on the AD or AS curve. Though not shown here, an equally important feature of this approach is that it allows comparisons of intertemporal changes of model reactions as well as of different models, revealing model features that escape traditional multiplier analysis. In short, IS/LM-AD/AS curves are a useful device to illustrate in a telling, transparent way the locations of change of the macro structure and their consequences, or, at least, of macroeconometric models.

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Appendix

Table A1: Effects of demand-side impulses on selected variables (Simulations IIa & IIb)
Percentage differences from baseline and elasticities

Year	Y	P	i	ε_{LM}[c]	ε_{IS}[c]	ε_{AS}[d]	W	Y/N
	% Differences			Elasticities			% Differences	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Simulation IIa: increasing governmental construction outlays[a]							
1st	0.2	0.0	0.8	0.3	-	13.4	0.2	0.1
2nd	0.3	0.1	2.1	0.1	-	3.3	0.4	0.0
3rd	0.2	0.2	2.0	0.1	-	1.6	0.5	-0.0
	Simulation IIb: increasing money stock[b]							
1st	0.0	-0.0	-9.7	-	-0.0	-48.4	0.0	0.0
2nd	0.0	0.0	-22.0	-	-0.0	22.3	0.0	0.0
3rd	0.0	0.0	-18.6	-	-0.0	4.2	0.0	0.0

Authors' computations. Y – real GDP, P – GDP price deflator, i – short-term nominal interest rate, W – nominal wage rate, Y/N – labour productivity. a) A permanent increase of one billion euros per quarter with a constant nominal money stock. b) A permanent increase of 10 percent. c) $\varepsilon_{LM,\ IS}$ = (1)/(3). d) ε_{AS} = (1)/(2).

Table A2: Macroeconomic effects of demand- and supply-side impulses
Absolute differences from baseline

	Simulation I[a]			Simulation II[b]			Simulation III[c]		
	Year 1	Year 2	Year 3	Year 1	Year 2	Year 3	Year 1	Year 2	Year 3
Origin									
Persons in employment, in 1000	49.7	94.1	103.8	2.8	9.7	13.0	-1.0	-26.0	-64.0
Real demand, in bn euros									
Private consumption expenditure	0.9	1.5	1.5	0.4	0.6	0.6	1.5	1.9	1.6
Public consumption expenditure	0.2	0.6	0.6	0.0	0.1	0.1	0.0	0.1	0.0
Gross fixed capital formation	5.0	5.1	4.8	0.1	0.5	0.5	-0.4	-1.4	-3.4
Machinery and equipment	0.8	0.8	0.4	0.1	0.2	0.1	-0.4	-2.1	-4.2
Construction	4.1	4.2	4.3	0.0	0.3	0.3	0.0	0.7	1.0
Changes in inventories	0.3	-0.0	-0.2	0.0	0.0	-0.0	0.1	-0.0	-0.1
Net exports	-2.2	-2.6	-2.2	-0.3	-0.5	-0.5	-0.6	-0.0	1.2
Exports	-0.7	-0.9	-1.0	-0.0	-0.1	-0.1	-0.3	-1.2	-2.5
Imports	1.5	1.7	1.2	0.3	0.4	0.4	0.3	-1.2	-3.7
Gross domestic product	4.1	4.7	4.5	0.3	0.6	0.6	0.6	0.5	-0.6
Prices, index									
Private consumption expenditure	-0.0	0.0	0.1	-0.0	-0.0	0.0	0.2	0.6	1.1
Gross domestic product	0.0	0.1	0.2	-0.0	0.0	0.0	0.3	0.8	1.5
Income distribution, in bn euros									
Wages and salaries	1.5	3.3	4.2	0.1	0.3	0.5	5.7	11.5	17.7
Net wages and salaries	0.8	1.7	2.1	0.0	0.2	0.3	3.1	6.1	9.1
Negotiated wages and salaries, index	0.0	0.2	0.6	0.0	0.0	0.1	3.8	8.1	13.2
Unit labour costs, index	-0.0	0.0	0.0	-0.0	0.0	0.0	0.0	0.0	0.0
Entrepreneurial and property income	2.0	1.5	1.9	0.1	0.1	0.1	-1.6	0.0	3.7
Disposable income	1.0	1.6	1.5	0.1	0.2	0.1	1.6	2.0	1.8
Government revenue, in bn euros	1.8	3.4	4.2	0.1	0.3	0.5	4.3	8.9	14.6
Taxes	1.2	2.1	2.6	0.1	0.3	0.4	2.3	4.8	8.0
Social security contributions	0.5	1.2	1.6	0.0	0.1	0.2	2.0	4.2	6.7
Government expenditure, in bn euros	4.3	4.9	5.8	-0.1	-0.5	-0.7	3.0	8.2	15.5
Social benefits other than social transfers in kind	-0.1	-0.3	0.1	-0.0	-0.0	-0.0	0.3	2.3	5.7
Gross capital formation	4.0	4.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0
Budget deficit, in bn euros	-2.5	-1.6	-1.5	0.2	0.8	1.1	1.2	0.7	-0.9
Deficit ratio, in percent	-0.1	-0.1	-0.1	0.0	0.0	0.1	0.1	0.1	-0.1

Authors' computations. a) A permanent increase in government construction outlays of one billion euros per quarter with constant short-term nominal interest rates. b) A permanent decrease in short-term nominal interest rates by 100 basis points. c) A permanent increase in the annual rate of change of negotiated wages and salaries by one percentage point with constant short-term nominal interest rates.

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