Apartment House Prices and the Macroeconomy: Theoretical Analysis and Empirical Evidence

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Abstract

This study analyzes price-rent multipliers of rental apartment houses and their relationship with macroeconomic variables. The empirical part employs transaction data from Berlin, Germany, to construct a multiplier time series, which is then used to test investor rationality and to derive stylized facts. It turns out that the observed series does not contradict rationally set prices. The most interesting stylized fact is that multipliers and interest rates are positively correlated. A DSGE model is used to analyze the interaction of macroeconomic variables and prices in a theoretical framework. The model allows for time-varying discount factors and systematic interdependence between macroeconomic factors. We then compare the stylized facts generated by the structural model with observed empirical time series behavior.

Keywords: Business cycle, rational valuation formula, vector autoregressive models.
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1 Introduction

Any asset investment means spending money today in the hope of receiving a stream of income in the future. Given the income accrues in the future, expected income has to be discounted to account for time of waiting and risk. In the case of real estate the future income consists of rental payments after the deduction of any operating costs. Given the above reasoning, one should observe, in a given market, that investors pay high prices for properties when they expect rents to rise or discount rates to fall. Conversely, they will pay low prices when they expect rents to fall or discount rates to rise. This alone does not suffice to term investors in a market as rational. For this, investors' expectations must be reasonable and, at least on average, in accordance with observed trends of rents and discount rates. Tests for investor rationality in property markets are based on this general idea and, in effect, compare observed prices with rational formed market values. To calculate the latter, one has to make assumptions on how rational investors form their expectations of market values, i.e., on the process of rents and discount rates. Thus, tests of investor rationality are always joint tests of the model used to derive rational market values and the behavior of investors in the market. For an overview of such tests see Campbell et al. (1997), Engsted (2002), and with respect to real estate Hendershott et al. (2005).

In forming their expectations, rational investors will take into account the whole institutional setting of the respective market and will have a structural model of the economy in mind. Econometric tests of investor rationality, however, are based on reduced form models. Although there is no need for structural models in the econometric tests, such models might be helpful in understanding observed investor behavior. The set of studies that use structural models for the interaction between asset prices and macroeconomic variables is rather small. Bernanke and Gertler (1999, 2001) augment the Bernanke et al. (1999) financial accelerator model with an asset price equation and analyze the performance of various monetary policy rules in this framework.

In this paper, we study the behavior of price-rent ratios (multipliers) of apartment houses and their interaction with the macroeconomy. Our unique data set consists of more then 10,000 transactions from Berlin during the years 1980 to 2004. Apartment houses are of interest for several reasons: first, rental income from these buildings depends directly on the income of private households, which is closely linked with the whole economy. Accordingly, the connection between apartment house prices and macroeconomic variables should be close. Second, it is reasonable to expect that participants in the apartment house market behave rationally. Purchasing an apartment building requires a large amount of money, about 813,000 EUR on average, and comes with extensive management requirements.[1] It is reasonable that investors, mostly wealthy private households, behave in well considered way. Third, investor behavior in apartment house markets is (to the authors' knowledge) not researched yet, mainly because in most industrial countries the market is rather small, making it difficult to obtain reliable market information. However, the share of rental housing in Germany is large, approximately 57% in the year 2000. In Berlin, Germany's capital and largest city of about 3.5 Million inhabitants, this share is even higher and amounts to about 90% of the 1.9 Million residential dwellings. About 77% of these dwellings are in the private rental market.[2] Moreover, information on rents is easily obtained from rent-surveys that local authorities are obliged to publish regularly, thus investors can gain insight into the market.

The structure of the paper is as follows: First, it discusses the rational valuation formula (RVF) and explains how to test for rational behavior in the market for apartment houses. Then, the VAR approach described by Campbell and Shiller (1987, 1988) is applied to investigate the extent to which apartment house prices in Berlin were set rationally and in accordance with the RVF. Depending on the additional assumptions we make, we find that the RVF can be supported by the data in terms of the VAR-based statistics. Second, we analyze the impact of macroeconomic factors on apartment house prices in a theoretical model under the assumption that investors form rational expectations and value rental income according to the RVF.

We use a stylized macroeconomic model in the New Neoclassical Synthesis (NNS) framework to show how the systematic interaction of macroeconomic variables affects rationally set asset prices, and analyze the co-movement of real estate prices and macroeconomic variables during the business cycle. We compare the theoretical results with the observed behavior of the Berlin apartment house multipliers. We contrast the empirical results with the stylized facts generated by structural macromodels that include the RVF. Using a small stylized macroeconomic model to capture the interdependence between the determinants of multipliers, we can show that the multipliers and interest rates are only negatively correlated if demand shocks dominate. If the variance of cost push shocks is larger than the variance of demand shocks, then interest rates and multipliers are positively correlated in our theoretical model.

Our results provide a basis for interesting future research. The theoretical analysis of this paper focuses on the channels through which monetary policy affects real estate prices. In principle, the model framework could be extended to study the effects of real estate prices on the macroeconomy. A thorough understanding of such feedback effects is important for conducting optimal monetary policy. Moreover, it would be of great interest to analyze the behavior of apartment house multipliers in other cities and countries.

2 Investor rationality

2.1 Rational valuation formula (RVF)

A rational investor will value an apartment building investment according to its present value. Let D_t denote the net operating rental income of an apartment building, H_t the required return rate that compensates for the risk of rental cash flows, then the market value is

$$V_t = \mathcal{E}_t \left[\sum_{j=1}^{\infty} \frac{D_{t+j}}{\prod_{k=1}^{j}(1 + H_{t+k})} \right] , \tag{1}$$

where $\mathcal{E}_t[\cdot]$ is the conditional expectation operator. Dividing both sides of (1) with the current net operational rental income D_t gives the multiplier

$$M_t = \mathcal{E}_t \left[\sum_{j=1}^{\infty} \frac{\prod_{i=1}^{j}(1 + G_{t+i})}{\prod_{k=1}^{j}(1 + H_{t+k})} \right] , \tag{2}$$

where G_t is the rental growth rate and $M_t \overset{\text{def}}{=} V_t/D_t$. Real estate professionals often use the multiplier or its inverse, the cap rate, to convey information on the current state of the market. The higher the multiplier, the more current investors pay for a building given its current rental income. Given the current rental income, D_t, rational investors will pay more for an apartment building

1. the higher the expected growth of future rental income, G_t
2. the lower the required return rate H_t

It is reasonable to assume that the expected growth of future rental income is closely linked with GDP growth of the region in which the apartment building is located. A higher GDP in the region means more available household income to spend on housing and, given a fixed housing stock in the short-run, higher rental prices for existing apartments. There are two important caveats with respect to this argument

1. households will only increase their housing consumption if they perceive the increase of real income as permanent
2. institutional constraints, mainly of rent law, may lead to a sluggish adjustment process

An example of the second caveat is the German rent law, where rent increases for sitting tenants are curtailed to 20% during three years. Further the rent of an apartment must not differ from rents of comparable apartments. Both aspects do not preclude that rents will adjust, but rents will do this slower than they would otherwise.[3]

2.2 Multipliers for Berlin apartment houses

Figure 1 plots the multiplier series for Berlin apartment houses, the growth rate of Berlin's GDP and the German 3-month interest rate. Appendix A.1 describes the data in detail. Referring to the multiplier equation (2), expressed for quarterly data, the GDP growth rate can be seen as a proxy for G_t and the interest rate will be related to the required return H_t. It is reasonable that the required return moves in the same direction as the interest rate.

[Figure 1 about here.]

The first exhibit of Figure 1 shows that the nominal 3-month interest rate, Berlin's nominal GDP growth and the multiplier all vary pro-cyclically. The correlation coefficient for the interest rate and the multiplier is 0.48. The second exhibit shows that the real figures behave pro-cyclically also; the correlation coefficient for the real interest rate and the multiplier is 0.38. One could say this is puzzling, arguing that higher interest rates make financing more expensive, which should have a depressing effect on prices and thus on multipliers. However, considering the expression for the multiplier, (2), reveals this argument ignores that rental income and required return rates may move in the same direction. If interest rates are high when income growth is high, then the net effect on multipliers is unclear, i.e., the net effect on M_t can be negative, zero and even positive.

One may ask if the pro-cyclicity of multipliers and interest rates during the sample period was only specific for Berlin. The main obstacle to answer this question is the lack of reliable transaction data for other German cities. However, we can give some indicative evidence that multipliers in other German cities also behaved pro-cyclical. Figure 1 presents the changes of multipliers for different cities provided by the RDM, an organization of real estate agents.[4] These results are by no means conclusive and there are a few cities were multipliers seem hardly ever to change, like Essen and Köln. However, the behavior of the multipliers in München, Frankfurt (at least for buildings built after 1949), Stuttgart, Hannover and Nürnberg indicate that Berlin was not special and that a positive relationship between interest rates and multipliers is common. Figure 2 shows the quarterly nominal and real GDP growth rates for Berlin and Germany and Figure 3 the consumer price indices.

[Figure 2 about here.]

[Figure 3 about here.]

In both cases it is clear that there are differences in the behavior of the time series, especially with respect to the GDP growth in the late Nineties, but these difference are too small to make Berlin special.

2.3 Test of the RVF

To test for investor rationality in the Berlin apartment house market, we apply the tests proposed by Campbell and Shiller (1987, 1988), see also Cuthbertson et al. (1997). These tests are based on a linear approximation of the RVF (2). We detail below how to derive this approximation and the additional assumptions we make to implement the tests.

Consider the log one-period ex-post return rate of an apartment house investment

$$h_{t+1} = \ln(P_{t+1} + D_{t+1}) - \ln P_t \ ,$$

where P_t is the price of the house at the end of period t, that is after payment of rents. D_t denotes the rental income in period t. Observe that the return rate

Table 1: Change of 3-month interest rate and RDM multipliers for different German cities, 1989-2004. Interest rate and multipliers always refer to the first quarter of the year. 1 indicates a positive, 0 no and -1 a negative change.

Year	**Change 3**	**Change of RDM multiplier, buildings built before 1949**												
	Month IR	Berlin West	Hamburg	München	Köln	Essen	Frankfurt	Dortmund	Stuttgart	Düsseldorf	Bremen	Duisburg	Hannover	Nürnberg
1989	1	1	1	1	1	0	1	0	1	1	0	1	1	-1
1990	1	1	1	1	1	0	1	0	1	1	1	1	0	1
1991	1	1	0	1	1	0	-1	0	1	0	-1	0	0	1
1992	1	-1	0	0	0	0	0	0	1	0	1	0	1	0
1993	-1	1	0	-1	0	0	-1	1	1	-1	1	0	0	0
1994	-1	-1	0	-1	1	1	1	1	-1	1	1	0	0	0
1995	-1	1	0	-1	0	0	-1	0	-1	1	0	0	1	0
1996	-1	-1	0	-1	0	0	0	0	-1	0	0	0	-1	-1
1997	-1	-1	0	0	0	1	-1	0	1	-1	0	1	-1	-1
1998	1	-1	0	-1	0	0	0	-1	-1	0	0	0	-1	1
1999	-1	-1	1	0	0	0	1	0	-1	0	0	0	0	-1
2000	1	0	-1	1	0	0	-1	1	-1	0	-1	0	0	1
2001	1	0	-1	1	0	0	0	1	-1	-1	-1	-1	0	0
2002	-1	.	-1	0	0	0	1	0	-1	0	0	0	0	-1
2003	-1	.	-1	-1	-1	-1	-1	-1	-1	0	-1	-1	-1	-1
2004	-1	.	-1	0	0	-1	0	-1	-1	-1	-1	-1	-1	-1

Year	**Change 3**	**Change of RDM multiplier, buildings built after 1948**												
	Month IR	Berlin West	Hamburg	München	Köln	Essen	Frankfurt	Dortmund	Stuttgart	Düsseldorf	Bremen	Duisburg	Hannover	Nürnberg
1989	1	-1	1	1	1	0	0	0	1	1	0	1	1	0
1990	1	1	1	1	1	0	1	1	1	0	1	1	0	1
1991	1	1	0	1	0	0	-1	0	1	0	-1	0	0	1
1992	1	-1	1	0	0	0	0	0	1	0	0	0	1	-1
1993	-1	-1	0	-1	0	0	-1	1	0	-1	0	0	0	1
1994	-1	-1	0	-1	1	1	1	1	-1	0	1	0	1	0
1995	-1	1	0	1	0	1	-1	0	-1	-1	1	1	-1	-1
1996	-1	-1	0	-1	0	0	-1	-1	1	0	0	0	-1	-1
1997	-1	-1	0	-1	0	1	-1	-1	1	0	0	1	-1	-1
1998	1	-1	-1	-1	0	0	0	0	-1	0	-1	1	-1	1
1999	-1	-1	1	0	0	0	1	0	-1	0	0	0	0	-1
2000	1	0	-1	1	0	0	-1	1	-1	0	-1	1	0	0
2001	1	1	-1	1	0	0	0	1	-1	-1	-1	-1	0	-1
2002	-1	.	-1	1	-1	0	1	0	-1	0	-1	0	0	1
2003	-1	.	-1	-1	-1	-1	-1	0	-1	0	-1	-1	-1	-1
2004	-1	.	0	0	0	-1	0	-1	-1	-1	-1	-1	-1	1

equation holds irrespective if it is expressed in nominal or real terms.[5] A linear approximation of the return rate is

$$h_{t+1} \approx \kappa + \rho(p_{t+1} - d_{t+1}) + d_{t+1} - p_t \tag{3}$$

(Campbell and Shiller 1988), where $p_t = \ln P_t$, $d_t = \ln D_t$ and

$$\begin{aligned} \theta &\stackrel{\text{def}}{=} \exp\{\mathcal{E}[d-p]\} \\ \rho &\stackrel{\text{def}}{=} \frac{1}{1+\theta} \\ \kappa &\stackrel{\text{def}}{=} \ln(1+\theta) - \frac{\theta \ln \theta}{1+\theta} \, . \end{aligned}$$

θ is the long run cap rate, i.e., the inverse of the multiplier. The parameter θ has to be set to implement the tests. We set the yearly cap rate to 5%, which corresponds to a multiplier of 20.[6] In this case, $\rho = 0.988$ and $\kappa = 0.067$. Observe, that the above approximation also holds when net operating rental income is not observed, but proportional to the observed rental income. In that case, the constant κ includes the constant factor of proportionality.

Rearranging (3), subtracting d_t on both sides, and defining $m_t \stackrel{\text{def}}{=} p_t - d_t$ gives

$$m_t = \kappa + \rho m_{t+1} + \Delta d_{t+1} - h_{t+1} \, .$$

Assuming rational expectations and taking conditional expectations gives the following equation

$$m_t = \kappa + \rho \mathcal{E}_t[m_{t+1}] + \mathcal{E}_t[\Delta d_{t+1}] - \mathcal{E}_t[h_{t+1}] \, , \tag{4}$$

which is no longer a definition but a theoretical model.

Iterating and assuming that the transversality conditions is fulfilled

$$\lim_{j\to\infty} \sum_{j=0}^{\infty} \rho^j \mathcal{E}_t[m_{t+j}] = 0 \, .$$

gives

$$m_t = \frac{\kappa}{1-\rho} + \sum_{j=0}^{\infty} \rho^j \mathcal{E}_t[\Delta d_{t+1+j}] - \sum_{j=0}^{\infty} \rho^j \mathcal{E}_t[h_{t+1+j}] \, , \tag{5}$$

which is a linear approximation of the RVF (2).

The intuition of the RVF tests applied below is as follows: construct a hypothetical time series for the multipliers, m_t^*, using formula (5), and then compare it with the observed multipliers m_t. If investors behaved in a rational fashion and the model chosen to construct m_t^* is correct, then the two series m_t^* and m_t should be statistically indistinguishable. Similarly, one can calculate the observed ex-post return rates

$$h_{t+1} \quad = \quad \kappa - m_t + \rho m_{t+1} + \Delta d_{t+1}$$

and compare them with the theoretical return rates

$$h_{t+1}^* \quad = \quad \kappa - m_t^* + \rho m_{t+1}^* + \Delta d_{t+1} \ .$$

To be specific, we employ the following statistical measures to conduct tests on rational investor behavior, see (Cuthbertson et al. 1997, p. 991):

1. $m_t = m_t^*$ directly imposes the restriction that observed and theoretical multipliers are identical. This restriction reduces to a non-linear Wald test of the model parameters.

2. The ratio of standard deviations of m_t and m_t^* should be equal to one.

3. The correlation of m_t and m_t^* should be equal to one.

4. The ratio of standard deviations of h_t and h_t^* should be equal to one.

5. The correlation of h_t and h_t^* should be equal to one.

Moreover, the behavior of the different series can be inspected visually.

To implement the tests, additional assumptions are required.[7] The first assumption is on the behavior of the required return rates h_t. Two different scenarios are implemented:

Scenario 1: constant real required return rate. In this case investors require a compensation for expected inflation, which corresponds to the Fisher hypothesis. Neglecting the constant rate, which is considered implicitly in the constant κ, the required one-period return rate is

$$\mathcal{E}_t[h_{t+1}] = \mathcal{E}_t[\pi_{t+1}] \ .$$

The inflation rate π_t is measured by the change of the consumer price index.

Scenario 2: required return equals the risk-free short term interest rate R_t plus a constant risk premium. This premium compensates for the risk embedded in an apartment house investment. Neglecting the constant risk premium, which is considered implicitly in the constant κ, the setting of this scenario is

$$\mathcal{E}_t[h_{t+1}] = R_t \ .$$

The second assumption is required, because rental real income growth is not observed. We proxy Δd_t by smoothing Berlin's real GDP growth Δy_t. The following formula is applied to obtain the time series of real rental income growth

$$\Delta d_t = (1 - \alpha)\Delta d_{t-1} + \alpha \Delta y_t \tag{6}$$

with $\alpha = 0.05$. Figure shows the smoothed real Berlin GDP growth series, where the series with $\alpha = 0.1$ is plotted for comparison.

[Figure 4 about here.]

The smoothing procedure is justified in two ways: first, households will adjust their consumption of housing only when they perceive income changes to be permanent. Smoothing of the GDP is a simple method to separate transitory shocks on real GDP growth from permanent changes and allows extracting of the permanent component. Second, smoothing may result from the way rents adjust in the market. It may be easier to adjust the rent for an apartment when a new tenant moves in than to adjust rents for sitting tenants. Assuming for the moment that: (i) rents for sitting tenants cannot be adjusted at all, (ii) the average tenant stays five years in an apartment before moving, (iii) rents of new contracts are proportional to the recent GDP, then the current rental income of an apartment building is a moving average of the GDPs of the previous twenty quarters. The real growth rate of rental income is then approximately the same as the smoothed GDP growth rate. Choosing an α that is higher than 0.05 is equivalent of assuming that rents for sitting tenants will be adjusted as well and that the average time of stay might be shorter than five years. Below, $\alpha = 0.1$ is considered as well.

2.4 Empirical tests: implementation and results

In what follows, we assume that all variables are demeaned. Let the vector x_t collect all relevant variables, where m_t is the first element of this vector. We assume that all variables follow jointly a vector autoregressive process of order one, VAR(1):

$$x_{t+1} = Ax_t + \varepsilon_{t+1} . \tag{7}$$

VARs of higher order can always be transformed into the VAR(1) companion form. The VAR is a reduced form model for the economic variables that influence growth of rental income and required return rates.

Given that the system is stable, which imposes restrictions on A, we obtain

$$\mathcal{E}_t[x_{t+1+j}] = A^{j+1}x_t . \tag{8}$$

Let e_i denote the column unit vector with a 1 in row i and 0 otherwise. Using this, we get for variable i in x_t

$$\sum_{j=0}^{\infty} \rho^j \mathcal{E}_t[x_{i,t+1+j}] = e_i^\top A(I - \rho A)^{-1} x_t . \tag{9}$$

Given an A and the approximation formula for RVF (5), the theoretical multipliers m_t^* can be computed.

Four VARs are fitted and used to compute theoretical multipliers. To be specific: Two different series of rental income are used, one computed with the smoothing parameter $\alpha = 0.05$, the second with $\alpha = 0.1$; for each series, two VARs are estimated, one that includes the multiplier m_t (VAR A) and one that does not (VAR B). The latter VARs are a robustness check of the results: The right-hand side of equation (4) reveals, the current multiplier does not depend directly on past or future multipliers and is not needed to calculate the theoretical series m_t^*. However, it is clear that past multipliers can convey information on expected future rental growth and required returns. Market participants value information on multipliers and cap rates, because it reveals other investors' perceptions of future rental income and required returns. Not including this information into the reduced form model is a conservative approach to test the RVF.

The vector x_t for the VAR without multipliers contains the growth rate of real rental income Δd_t, the nominal short term interest rate R_t and the Berlin inflation rate π_t: $x_t^\top = (\Delta d_t, R_t, \pi_t)$; the vector for the VAR with the the multiplier is accordingly: $x_t^\top = (m_t, \Delta d_t, R_t, \pi_t)$. The VAR coefficients are estimated using the ordinary least squares method. Lag order for all four VARs is two, as unanimously indicated by the information criteria according to Akaike, Schwarz and Hannan-Quinn. The maximal root of the estimated A matrices is always below one, indicating stability. We do not report detailed results and diagnostic statistics for the estimated VAR model here.

After bringing the estimated VARs into their VAR(1) companion form, the theoretical multipliers m_t^* are computed as follows (constant terms are neglected):

$$m_t^{*(1)} = e_i^\top A(I - \rho A)^{-1} x_t \tag{10a}$$

$$m_t^{*(2)} = (e_i - e_{i+1} + e_{i+2})^\top A(I - \rho A)^{-1} x_t \ , \tag{10b}$$

where $i = 2$ for the VAR A that does include the multipliers and $i = 1$ for the VAR B that does not. The theoretical multipliers and their observed counterparts are plotted in Figure 5 and 6.

[Figure 5 about here.]

[Figure 6 about here.]

The test statistics enumerated on page 10 are given in Table 2.

[Table 1 about here.]

Both visual inspection and statistical evidence show that the models under Scenario 2 indicate that prices were not set rationally. On the other hands, models under Scenario 1, assuming constant real required returns, fit the data well.

3 Price dynamics in a stylized macroeconomic model

The standard model for the analysis of short and medium term macroeconomic fluctuations is a dynamic stochastic general equilibrium (DSGE) model with nominal rigidities. Under certain assumptions it can be shown that the implications of such an optimizing model for the dynamic behavior of output, inflation rate and interest rate can be summarized in a small stylized model, see for example Galí (2002), King (2000) or Walsh (2003). A small stylized model of the New Neoclassical Synthesis (NNS) class consists at least of three equations: a New IS equation, the New Keynesian Phillips curve and a monetary policy rule (interest rate rule). Since we are interested in the behavior of the interest rate in response to different types of economic shocks, we apply a model version that explicitly allows for technology and demand shocks. A main difference between these two shocks in our model is that demand shocks have only transitory effects while technology shocks have a permanent effect on real output. The model of Galí et al. (2003) forms the basis of our analysis. In absence of any rigidities the economy produces and consumes the flexible price output in every period t. The natural logarithm of the flexible price output is denoted by y_t^*. The flexible output depends on the level of the flexible price output in the previous period, y^*_{t-1} and an autoregressive stationary ($\rho_a < 1$) productivity shock, $x_{a,t}$:

$$y^*_t = y^*_{t-1} + \psi x_{a,t} \ , \qquad x_{a,t} = \rho_a x_{a,t-1} + \varepsilon_a \ , \qquad \varepsilon_a \sim N(0, \sigma_a^2) \ ,$$

where the coefficient ψ depends on the specification of the utility function. We focus on the case in which income and substitution effects of changes in the real wage offset each other such that $\psi = 1$. Under the assumption of sticky goods prices, the economy fluctuates around the flexible price output. These fluctuations can be described by the New IS equation and the New Keynesian Phillips Curve. The IS equation reflects the consumption Euler condition and is specified in terms of the output gap $\tilde{y}_t$, the difference between actual output y_t and flexible price output:

$$\tilde{y}_t = \mathcal{E}_t[\tilde{y}_{t+1}] - \frac{1}{\sigma}\left\{R_t - \mathcal{E}_t[\pi_{t+1}] - r^*_t\right\} \ ,$$

where R_t is the one-period nominal interest rate, π_t is the inflation rate and r^*_t is the flexible price real interest rate:

$$r^*_t = r + \sigma\rho_a x_{a,t} + \sigma x_{d,t} \ .$$

r is the steady state real interest rate in absence of shocks, σ is the intertemporal elasticity of substitution and $x_{d,t}$ is a demand shock.[8] The New Keynesian Phillips Curve is derived from the forward-looking behavior of firms who know that prices will be sticky for some time and therefore consider expected future changes in marginal costs in the price setting decision. Under the assumption that real marginal costs depend on the relation between actual and flexible price output, we obtain the following Phillips curve

$$\pi_t = \beta E_t[\pi_{t+1}] + \gamma\tilde{y}_t + x_{\pi,t} \ ,$$

where γ depends on the degree of price stickiness and $x_{\pi,t}$ is a cost push shock. By allowing for habit persistence of consumers and for a fraction of backward-looking firms, the New IS and New Keynesian Phillips equations can include lagged output and lagged inflation, respectively. However, since we are not interested in deriving simulations that closely fit observed data but are interested in the co-movement of output, inflation rate and interest rate, we refrain from increasing the complexity of the model and stick to the highly stylized equations described before. The model is closed by an interest rate rule wich reflects monetary policy

$$R_t = r + \phi_\pi \pi_t + \phi_y \tilde{y} + x_{R,t} \ .$$

The nominal interest rate R_t is the monetary policy instrument. This depends on the observed inflation rate, output gap and a monetary policy shock $x_{R,t}$. The described set of equations forms our stylized macroeconomic model. The output gap, real GDP growth, inflation rate and interest rate are completely determined within this model. The house price multiplier equation is now added to the model. It should be noted that we do not consider interaction of house prices and macroeconomic fluctuations. In our model, house prices depend on macroeconomic variables, not vice versa. We leave the study of interaction and the analysis of optimal monetary policy in such a framework for further research. The main advantage of investigating house prices together with a stylized macroeconomic model is that the interaction between the right-hand side variables in the house price equation is explicitly considered and that the effects of various economic shocks on house price multipliers can be identified. In accordance with our reasoning in the previous section, we assume that real rent growth is given by smoothed real GDP growth (6)

$$\Delta d_t = (1-\alpha)\Delta d_{t-1} + \alpha \Delta y_t \ ,$$

where Δd_t is real rent growth and $\alpha \in \{0.05, 0.1\}$ in the two baseline cases. The multiplier equation, expressed in nominal terms, is

$$m_t = \kappa + \rho \mathcal{E}_t[m_{t+1}] + \mathcal{E}_t\left[\Delta d_{t+1} + \pi_{t+1}\right] - \mathcal{E}_t[h_{t+1}] \ .$$

Finally, the log discount rate h_{t+1} is a function of nominal interest rate and inflation rate. Scenario 1 for the required return rate is

$$\mathcal{E}_t[h_{t+1}] = \mathcal{E}_t[\pi_{t+1}]$$

and Scenario 2

$$\mathcal{E}_t[h_{t+1}] = R_t \ .$$

The model is solved for the recursive law of motion using Uhlig's toolkit (Uhlig 1999). The numerical values of the model parameters are the same as in Galí et al. (2003) and are given in Table 3.

[Table 2 about here.]

In the following, we discuss a selection of impulse responses calculated from the recursive law of motion and correlations of simulated house price multipliers and macroeconomic variables.

[Figure 7 about here.]

[Figure 8 about here.]

[Figure 9 about here.]

[Figure 10 about here.]

[Figure 11 about here.]

[Figure 12 about here.]

[Figure 13 about here.]

[Figure 14 about here.]

Selected impulse responses are depicted in Figures 7 to 14. The main conclusion that can be drawn from the impulse response analysis is that the correlation of the multiplier's and the nominal interest rate's reaction to economic shocks depends crucially on the nature of the shock.

In case of a productivity shock, specified with positive autocorrelation in our baseline scenario, both the nominal interest rate and the multiplier increase. After a positive productivity shock, households expect a higher income in the future and react by increasing current consumption. The increase in consumption is higher than the initial shock and thus widens the output gap. Since the output gap is an argument in the monetary policy reaction function, the central bank increases the nominal interest rate. The multiplier increases because the autocorrelated productivity shock produces a sequence of positive real GDP growth rates, which are expected by investors and therefore transmitted to the forward-looking multiplier. As can be seen in Figures 7 and 8, the reaction of the multiplier is larger in Scenario 1 than in Scenario 2. In the latter scenario, the positive effect of future expected GDP and rent growth is partially compensated by the negative effect of the nominal interest rate on the discount factor. However, the correlation between the multiplier and the nominal interest rate is positive in both scenarios if the supply side is the dominant source of shocks. The picture looks different in case of demand shocks.

Demand shocks are of a transitory nature, the initial increase in output and the output gap is followed by a sequence of negative real growth rates. These future negative growth rates are expected in the period in which the demand shock occurs such that the multiplier decreases. The effect is larger in Scenario 2, where the discount factor increases due to the increase in the nominal interest rate as response to the positive output gap. Figures 11-14 show the corresponding impulse responses to cost push shocks and monetary policy shocks. Interestingly, the sign of the correlation between interest rate response and multiplier response to these shocks depends on the underlying scenario.

We also have computed the correlation coefficients of simulated multiplier and macroeconomic series. They are shown in Table 4. Confirming the impulse response analysis we find that interest rate and multiplier are positively correlated if supply shocks dominate and and they are negatively correlated if demand shocks dominate. In case of cost push and monetary policy shocks, the correlation depends on the scenario.

[Table 3 about here.]

[Table 4 about here.]

The observed cyclical behavior of the multiplier and its positive correlation with real growth rate *and* interest rate (see Table 5) can be reproduced in a small theoretical model in which investors extract information on future rent growth from the observed growth rate of real GDP.

4 Conclusions

The motivation for this paper is twofold: First, we analyze the behavior of quarterly apartment house multipliers and macroeconomic variables for Berlin over a time period of 25 years. Second, we analyze the impact of macroeconomic variables on apartment house prices in a theoretical model under the assumption that investors are rational and value apartment houses according to the RVF.

Our results are as follows: We test if observed apartment house multipliers are in accordance with the RVF by applying the VAR based methodology developed by Campbell and Shiller (1987, 1988). It turns out that the RVF can explain the dynamics of multipliers. This result depends, however, on the scenario chosen for the behavior of required return rates. The hypothesis that investors were rational cannot be rejected if the real required return rate is constant; the hypothesis is reject if the required return rates equals the risk-free short term interest rate.

Furthermore, we contrast empirical stylized facts with correlations generated by a structural macroeconomic model. This model includes the RVF. The model shows that the multiplier and the interest rate are only negatively correlated if demand shocks dominate. If the variance of cost push shocks is larger than the variance of demand shocks, then interest rates and multipliers are positively correlated as it is the case for the empirical data.

Our results provide a basis for interesting future research. The framework can be extended to study the effects of house prices on the macroeconomy and in a further step to search for optimal monetary policy rules in presence of the interdependence between the macroeconomy and house prices.

A Appendix

A.1 Data description

This appendix reports the data used in this study.

Berlin gross domestic product: Berlin gross domestic product (GDP), real and nominal, 1970:1-2004:4. Data source is Berlin's Statistical Office (Statistisches Landesamt Berlin). The series for whole Berlin (West and East) starts in 1991 and is calculated backwards for 1970 to 1990 using the growth rates of the West Berlin GDP. These data have a yearly frequency. Quarterly data were then generated with the distribution technique proposed in (Chow and Lin 1971), where the quarterly GDP for Germany is used as related series.

German gross domestic product: German gross domestic product (GDP), real and nominal, 1970:1-2004:4. Data source is the German Federal Statistical Office (Statistisches Bundesamt). The series for Germany starts in 1991 and is calculated backwards for 1970 to 1990 using the growth rates of the West German GDP. Quarterly growth rates are computed as difference between log values.

Multiplier: Quality-controlled time series of price-rent ratios of apartment houses in Berlin, 1980:1-2004:4. m_t is the series in logs and M_t is the transformed index series with value 100 in the first quarter of 1980. Section A.2 describes the construction of the multiplier time series in detail.

Consumer price index Berlin: Consumer price index for Berlin, base year is 2000, 1979:2-2004:4. For the years before 1991, the consumer price index for households with average income in West Berlin is used. Data source is Berlin's Statistical Office (Statistisches Landesamt Berlin). Quarterly inflation rate is computed as difference between log values.

Consumer price index Germany: Consumer price index for Germany, base year is 2000, 1970:1-2004:4. Data source is the German Federal Statistical Office (Statistisches Bundesamt). Quarterly inflation rate is computed as difference between log values.

Short-term interest rate: 3-month money market rate reported by Frankfurt banks, fractions. Data source is Deutsche Bundesbank.

A.2 Calculating the constant-quality multipliers

This section describes the transaction data used to calculate the quarterly multiplier series. It also gives relevant institutional details on the housing market in Berlin.

The data on transaction of apartment houses are provided by the local Surveyor Commission for Real Estate out of its Automated Database (AKS).[9] We have information on 10382 sales transacted in the 100 quarters between 1980:1 and 2004:4. On average, there are 104 transactions per quarter, with a maximum of 252 and a minimum of 18.

[Table 5 about here.]

Table 6 reports summary statistics of the different variables. Each observation has information on the transaction price, the size of lot, and floor space, the age of the building, location and other discrete characteristic variables, and the yearly rent (either net or gross rent). Yearly gross rent is reported for 9178 observations and includes distributable costs like land tax, housekeeping services and insurance fees. Yearly net rent is reported for 1204 observations and equals gross rent minus distributable costs. Net rents are only equivalent to net operating rents (D in our notation) when the owner incurs no additional management and maintenance costs. Such non-distributable costs are not recorded in the data set, and may well depend on the characteristics of the property.

All transactions before the year 1991 are exclusively from West Berlin. Even after the Reunification in 1990, most of the transactions took place in the West of Berlin. Only 13.3% of all transacted buildings are located in the East of Berlin. The age variable reveals that all buildings were traded in the secondary market and were at least one year old on the date of sale. During the sample period, government support for newly constructed apartment buildings was generous. Support for new private rental housing consisted of the possibility to claim accelerated tax depreciation of construction costs from the income tax bill. Support for new social housing came in different forms such as direct subsidies and financing at reduced interest rates. Social housing support was associated with the restriction that the apartments had to be rented to low income households at a low rent. This restriction can be binding up to 30 years. Buyers of social housing buildings not released of this restriction are committed by law to accept existing rental contracts (Tomann 1990). The support for old buildings was in principle much less generous and consisted mainly in the possibility to claim special depreciation of modernization costs when the modernization increased the number of apartments in the building. However, after the Reunification the German Government introduced a law that allowed generous special depreciation for the modernization of old building in the East of the country.[10] The law was in effect until the end of 1998. In principle, prospects of future tax savings could have fuelled prices of Berlin apartment buildings after the Reunification.

Another important intervention of the Government into the market of existing apartment buildings consisted of the Berlin-specific rent regulation for buildings constructed before 1949. This regulation was in effect until the end of 1987. Rent increases for buildings under the regulation were set by the West Berlin Government. The effect of this regulation on multipliers is not obvious. Because there were administered rent increases, the regulation might not have been binding at all. If it was, then the regulation may have led landlords to neglect necessary building maintenance. This could have shortened the perceived remaining time of usage of such buildings, which could have resulted in multipliers lower than they had otherwise been.

The multiplier series m_t is computed with the use of hedonic regression. It takes into account that observed individual multipliers may deviate from the *average* multiplier because of property specific characteristics that influence non-distributable operating costs and because of unusual circumstances during the business dealings. It is also conceivable that specific building types may command specific risk premiums, in which case the approximation constant κ depends on building characteristics. We assume that such specific risk premiums, if they exist, are constant throughout the entire sample period and have no influence on multipliers' behavior over time.

Specifically, we fit

$$m_{n,t} = m_t + x_{n,t}\beta + \xi_{n,t} \ , \tag{11}$$

where the dependent variable is the observed log multiplier for building n that is sold in period t. The period constant is m_t and deviations of observed multipliers from the per-period average are a function of building characteristics collected in the row vector $x_{n,t}$. The first entry in $x_{n,t}$ is a one and an overall constant is included into the regression. There is no dummy for the first period, which is the normalization period. $\xi_{n,t}$ is a disturbance term that allows for unsystematic influences.[11] Dummies control for buildings with gross rents, buildings under rent control before 1988, buildings that were build as social housing, buildings that are legally partitioned in condominiums, properties located in a redevelopment area, dummies for the district in which the building is located and, for transactions after

1995, dummies for indicators of the quality in which a building is located. The continuous variables lot size, floor space, and age are transformed according to the following Box-Cox type functions

$$T(x, \lambda) = \begin{cases} \lambda^{-1} \left[\left\{ s^{-1}(x + a_\lambda) \right\}^\lambda - 1 \right] & \text{for } \lambda \in \Lambda, \\ \ln\left\{ s^{-1}(x + a_0) \right\} & \text{for } \lambda = 0 \end{cases} \tag{12}$$

with $\Lambda = \{-2, -1, -0.5, 0.5, 1, 2\}$. Here, x denotes any of the continuous explanatory variables, a_λ is a constant depending on λ, s is the sample standard deviation of variable x and λ is the parameter that determines the transformation. A particular value of λ implies a value of the constant a_λ. These constants are computed according to the suggestions made in Bunke et al. (1999) and aim to make, for any given λ, the transformation as nonlinear as possible. All transformations are strictly increasing in x.

Given that we have three continuous variables, there are $7^3 = 343$ possible transformation combinations. The best combination of transformations is selected with the help of the R^2-type standardized cross-valuation criterion

$$CVS = 1 - \frac{\sum_{t=1}^{T} \sum_{n=1}^{N_t} (m_{n,t} - \widehat{m}_{-n,t})^2}{\sum_{t=1}^{T} \sum_{n=1}^{N_t} (m_{n,t} - \overline{m})^2} \,. \tag{13}$$

Here, T is the number of periods, N_t is the number of observations in period t, and $\widehat{m}_{-n,t}$ denotes the predicted value of $m_{n,t}$ calculated with an OLS regression in which observation (n, t) has not been used. Running stepwise regressions for all transformation combinations, the final combination is found as the one that maximizes CVS; for more details see Schulz and Werwatz (2004).

Tables 7 and 8 give the results of the two hedonic regressions, where location in the first is solely modelled via district dummies, whereas in the second indicators for the quality of the neighborhood are included. We run two separate regressions, because the quality indicators are only available since 1996. They do a fairly good job and are highly significant, see Table 8. The indicators are a more parsimonious way to measure location effects and reduce the number of significant district dummy coefficients by 12.5%.

[Table 6 about here.]

[Table 7 about here.]

The Wald-Statistics of both regressions indicate that building specific characteristics have important effects on individual multipliers. Simple arithmetic averages of multipliers would lead to a biased time series.

There are two main differences between the regressions. Firstly, the selected transformation function for floor space is different. However, this is only a minor difference. If the transformation combination of the second regression $(-0.5, 0, -2)$ is applied to the data of the first one, the resulting CVS is very close to 0.551.[12] Secondly, the coefficient for the redevelopment area indicator is only significant in the first, not the second regression. Generally, one should expect a significant negative coefficient because redevelopment can be a lengthy procedure and property rights of owners are curtailed (for example, every sale has to be approved by the council). According to the first regression and given a level of rental income, the price is about 10.1% lower if a building is located in a redevelopment area.[13] A possible explanation for an insignificant coefficient in the second regression is the fact that 91% of all buildings in a redevelopment area have also a simple location. Multipliers are by about 9.7% smaller when a building has simple location, about the same magnitude as when the building is located in a redevelopment area.

Lot size has a positive influence on multipliers whereas the floor space has a negative impact. This may indicate that 'more dense' properties command a lower price given the rent. Such buildings are mainly located in low quality inner-city districts and might be more costly to manage. The age variable controls implicitly for the unobserved remaining time of usage of a building. The longer a building can be used, the more rent can be generated and the higher should be the multiplier. A new buildings has, ceteris paribus, a higher multiplier than an old building, but the estimated relationship is not strictly monotone. The discount for very old buildings is smaller than for middle-aged buildings.

Expectedly, buildings with reported gross rents have smaller multipliers. According to the estimates, distributable operating costs are around 23%.[14] Multipliers are higher by 11% for buildings that serve as social housing. Apartments in such buildings might be under rent control, but once the binding period of up to 30 years has expired, apartments can be let at market rents.[15] These growth opportunities and the low current rent level justify the positive coefficient. Buildings which are legally partitioned in (still rented) condominiums command a flexibility premium of about 7%. The owner of a legally partitioned property can sell apartments piecewise in the future, which alleviates the locked-in effect of his investment.

Although the number of yearly transactions on the Berlin real estate market remained stable throughout the sample period, the number of observations in our data set for later years is quite small. This comes from the fact that it has become recently complicated for the surveyors of the GAA to obtain information from owners that is not recorded on sales contracts. Rental income is an example such information. Due to the small number of quarterly observations used in the second regression, the estimated multipliers exhibit a large amount of between-period variation. We decided to smooth the series by replacing the multiplier for period t with the weighted average of the previous, current and following $\widehat{m}_t$, where the weights are

$$w_{t,t+i} = \frac{\widehat{\sigma}_{t+i}^{-2}}{\widehat{\sigma}_{t-1}^{-2} + \widehat{\sigma}_t^{-2} + \widehat{\sigma}_{t+1}^{-2}} \qquad i \in \{-1, 0, 1\} \ .$$

$\widehat{\sigma}_t$ is the estimator of the standard error for $\widehat{m}_t$. The smoothed series exhibits a between-period variation that is very similar to the multiplier series estimated with the first regression.

A final remark: most of the analysis is conducted with logarithmized data. In that case the estimated log multiplier time series is used. However, in the overview on the Berlin market, we use the transformed series $\widehat{M_t}$, which is 100 for 1980:1. The index values are computed according to

$$\widehat{M_t} = 100 \exp\left\{\widehat{m}_t - 0.5\widehat{\sigma}_t^2\right\}$$

and are corrected for small-sample bias, see (Kennedy 1998, p. 37). Here, $\widehat{\sigma}_t^2$ denotes the robust estimator for the variance of $\widehat{m}_t$.

A.3 Non-linear Wald test statistic

The null hypothesis is

$$\mathrm{H}_0 : \qquad m_t = m_t^*$$

for all t; the alternative is $m_t \neq m_t^*$ for at least one t. Now, for the VAR with included multiplier, $m_t = e_1^\top x_t$ and the null becomes with (10)

$$\mathrm{H}_0 : \qquad e_1 = f(a) \ ,$$

where $f(a)$ is the respective right-hand side of (10) and a are the unknown coefficients of the VAR(1) model. For example, in the case of constant real required return rate we have

$$f(a) = \left\{ e_2^\top A(I - \rho A)^{-1} \right\}^\top$$

and a are the stacked coefficients of the A matrix. A has J columns. Notice that $f(a)$ is a $(J \times 1)$ vector valued function

$$f(a) = \begin{bmatrix} f_1(a) \\ f_2(a) \\ \vdots \\ f_J(a) \end{bmatrix} .$$

Let $\widehat{a}$ denote the $N \times 1$ vector of estimators for the VAR(1) coefficients, then the Wald statistic (a scalar) is

$$W = \{f(\widehat{a}) - e_1\}^\top \mathcal{V}[f(\widehat{a}) - e_1]^{-1} \{f(\widehat{a}) - e_1\} \ ,$$

which is $\chi^2(J)$-distributed under the null.

If $f(a)$ is nonlinear, then $\mathcal{V}[f(\widehat{a}) - e_1]$ is approximately given by

$$\nabla f(\widehat{a}) \widehat{\mathcal{V}}[\widehat{a}] \nabla f(\widehat{a})^\top \ , \tag{14}$$

where $\nabla f(\widehat{a})$ is the $(J \times N)$ Jacobian matrix of $f(a)$

$$\nabla f(a) = \begin{bmatrix} f_{11}(a) & \dots & f_{1N}(a) \\ \vdots & \ddots & \vdots \\ f_{J1}(a) & \dots & f_{JN}(a) \end{bmatrix}$$

evaluated at $\widehat{a}$ (Greene 2003). f_{jn} is the partial derivative of function f_j with respect to coefficient a_n. The approximation of the covariance matrix with (14) is also known as delta-method.

Let e_n denote a unit vector with a 1 in row n and zeros otherwise. Then the n's column of the Jacobian matrix can be calculated numerically with

$$\nabla f(a)_n \approx \frac{f(a + e_n\delta_n) - f(a - e_n\delta_n)}{2\delta_n} \ ,$$

where

$$\delta_n = (10^{-7})^{1/3} a_n \ ,$$

see also Press et al. (1992, 5.7).

Notes

[1]The usual Berlin apartment house has more than 20 apartments.

[2]Numbers are for the year 2000, see Senatsverwaltung für Stadtentwicklung und Investitionsbank Berlin (2002). 22.9% of all rental dwellings in Berlin are social housing, which means that they have to be rented to entitled low income households at rents well below the market level. Owners of social housing properties obtain generous state support.

[3]The two-yearly rent-surveys are needed to facilitate the comparison of rents. During most of the sample period, the maximal allowed increase of rents was 30%. The intention of the regulation is to prevent rents in old contracts from lagging too much behind new contracts and to guarantee for a low dispersion of rents for comparable properties.

[4]In the first quarter of every year, the RDM surveys its members on the current situation on real estate markets in Germany. One question is on current multipliers for apartment houses. The information can be seen as a rough indicator for the state of the real estate market.

[5]In what follows, whenever necessary, we emphasize when a variable is in nominal terms.

[6]This expert-guessed figure is recommended in German Guidelines on Valuation for income valuation of apartment houses.

[7]As was said above, rejecting of the RVF tests can happen out of two reasons: we made the correct assumptions, but investors behaved irrational or because we made the wrong assumptions.

[8]Galí et al. (2003) do not consider demand shocks, see Woodford (2003) and Walsh (2003), for example, for the role of demand shocks in NNS models.

[9]According to the German Building Law (Baugesetzbuch, BauGB) notaries are obliged to sent copies of contracts for sale of properties to the Surveyor Commission (Gutacherausschuss für Grundstückswerte) in their respective state. Surveyor commissions have to store the data and use it to provide information on the real estate market (§§ 192-199 BauGB).

[10]The intention of the law was to improve the housing stock in the East part (Gesetz über Sonderabschreibungen und Abzugsbeträge im Fördergebiet). The special tax depreciation allowance applied to the whole reunited Berlin. It allowed deduction of up to 50% of the modernization costs during just five years, which gave high income tax paying owners the opportunity to reduce their tax bill and to shift (rental) income to later years.

[11]A transaction price may deviate from the price marginal sellers and investors would bargain because of uninformed parties or time pressure during the sale. We assume that such deviations are not systematic but totally random.

[12]The coefficient for the floor space transformed with $\lambda = 0$ is -0.15. However, the coefficient of the square of this variable is also significant at the 5% level.

[13]Percentage changes of multipliers due to discrete characteristics are calculated as $(\exp\{\widehat{\beta}_d\} - 1)\%$, where $\widehat{\beta}_d$ is the estimated coefficient for the respective dummy variable.

[14]Here and in the following cases, the figures are chosen so that they always lie in the respective estimated 95% confidence intervals for both regressions.

[15]About 75% of all social housing buildings are at least 24 years old on the date of sale.

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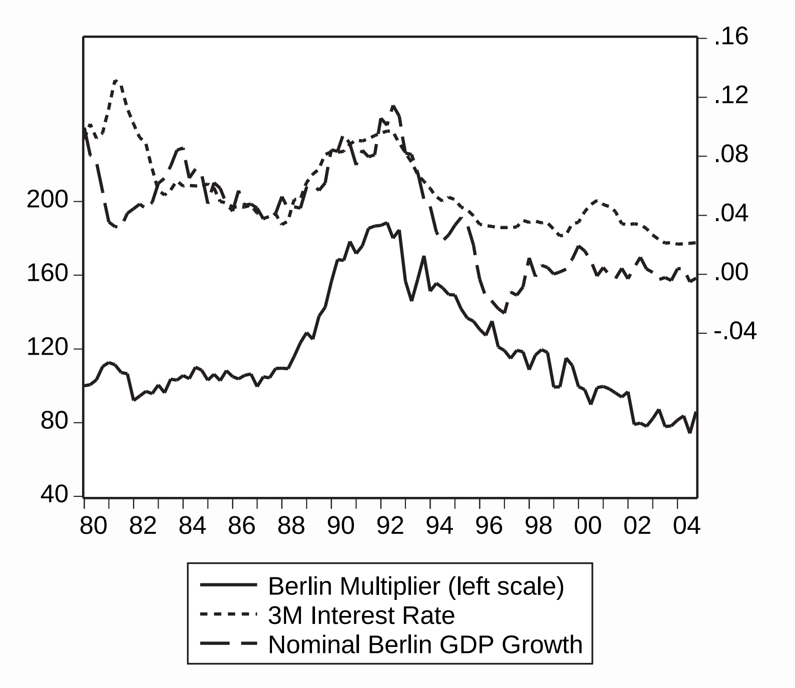
List of Figures

Figure 1: Quarterly multiplier for Berlin apartment houses, Berlin GDP growth rate and German 3-month interest rates, 1980:1 to 2004:4. First exhibit shows the multiplier with nominal GDP growth and the nominal interest rate, second exhibit shows multiplier with real GDP and the real interest rate.



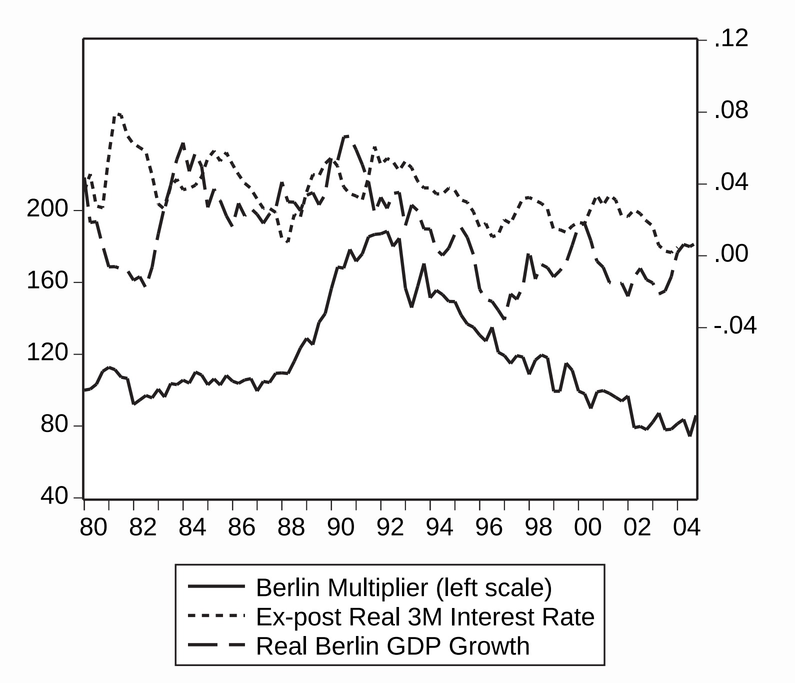
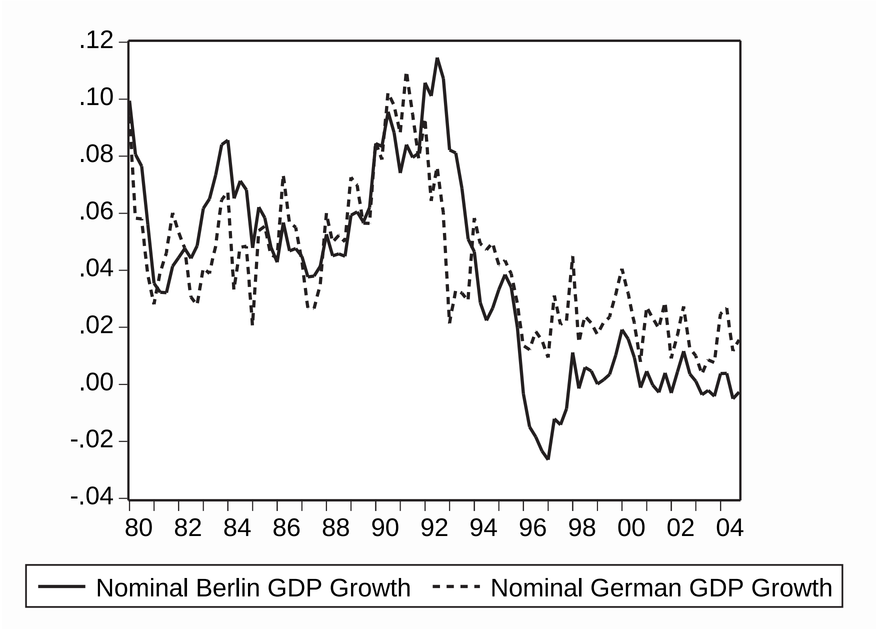


Figure 2: Quarterly GDP growth for Berlin and Germany, 1980:1 to 2004:4. First exhibit shows nominal GDP growth and second exhibit shows real growth.



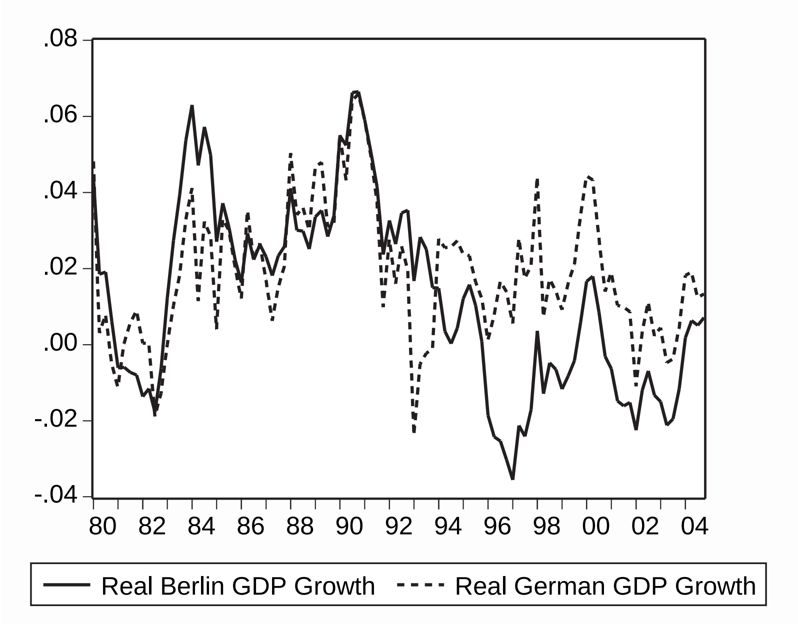


Figure 3: Quarterly consumer price index for Berlin and Germany, 1980:1 to 2004:4.

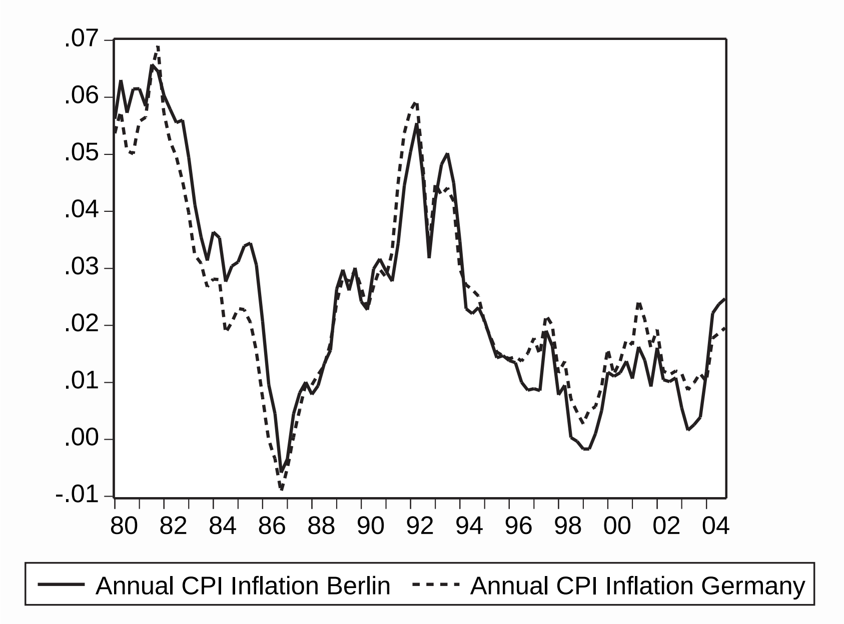


Figure 4: Quarterly real growth of rental income for Berlin, 1980:1 to 2004:4. Growth rates are computed by smoothing the real GDP growth rates, smoothing coefficients are $\alpha \in \{0.05, 0.1\}$, see equation (6).

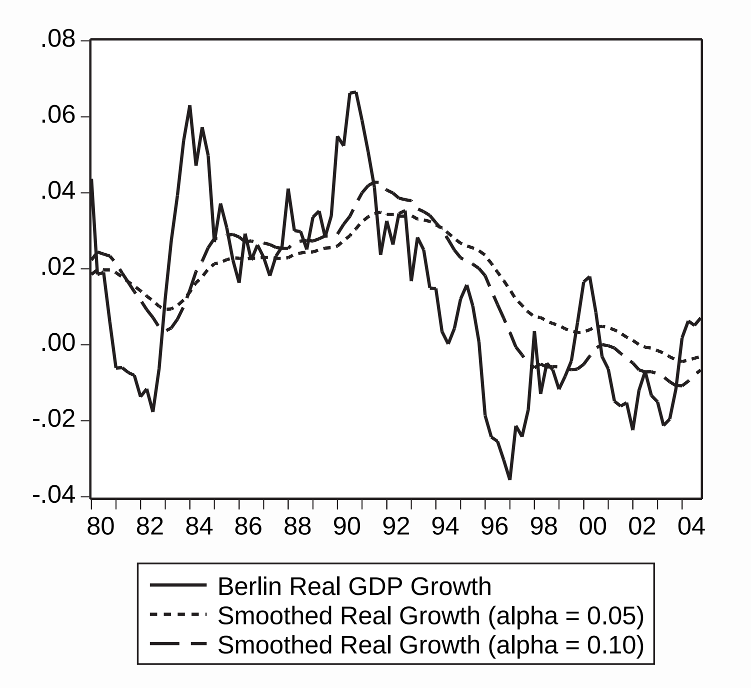
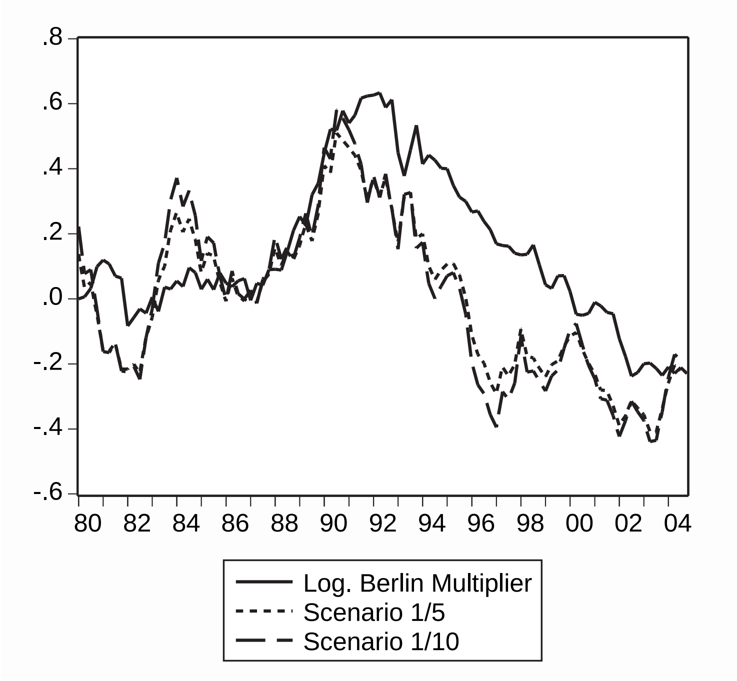


Figure 5: Theoretical and observed multipliers, m_t^* and m_t, for the two scenarios for the required return rates, 1980:1 to 2004:4. Theoretical multipliers are calculated with the help of VAR A that includes multiplier time series. Scenario 1 assumes a constant real required return rate, Scenario 2 assumes a required return rate that consists of the short term risk-free interest rate plus a constant risk premium. 5 and 10 indicate the smoothing parameter used to construct the rental growth rate Δd_t.



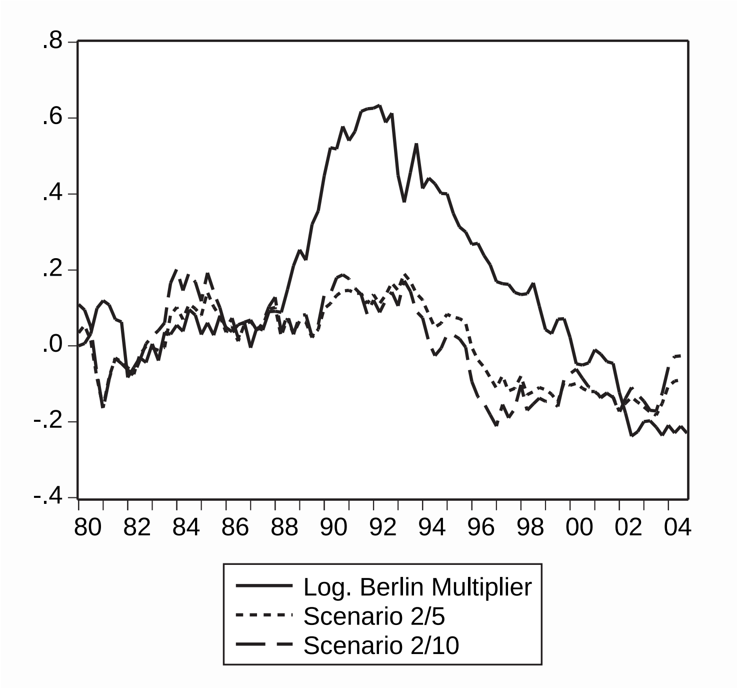
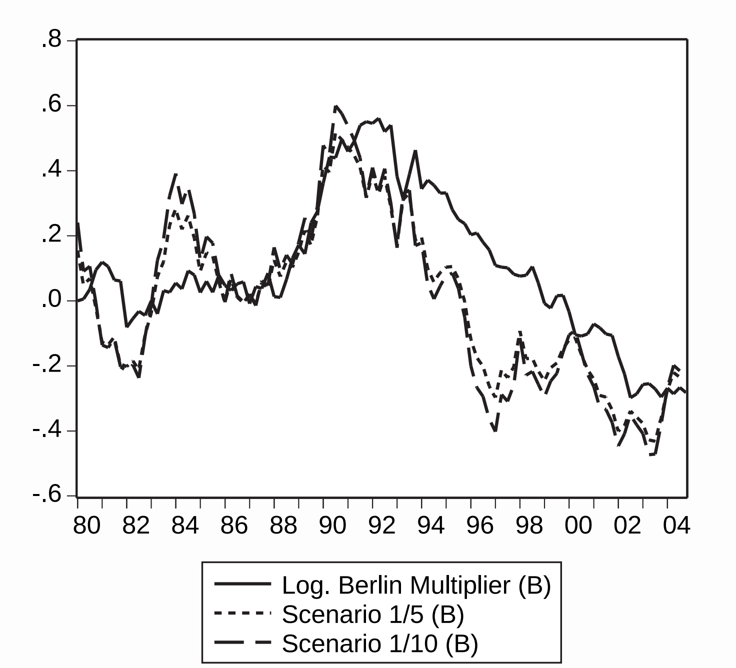


Figure 6: Theoretical and observed multipliers, m_t^* and m_t, for the two scenarios for the required return rates, 1980:1 to 2004:4. Theoretical multipliers are calculated with the help of VAR B that excludes multiplier time series. Scenario 1 assumes a constant real required return rate, Scenario 2 assumes a required return rate that consists of the short term risk-free interest rate plus a constant risk premium. 5 and 10 indicate the smoothing parameter used to construct the rental growth rate Δd_t.



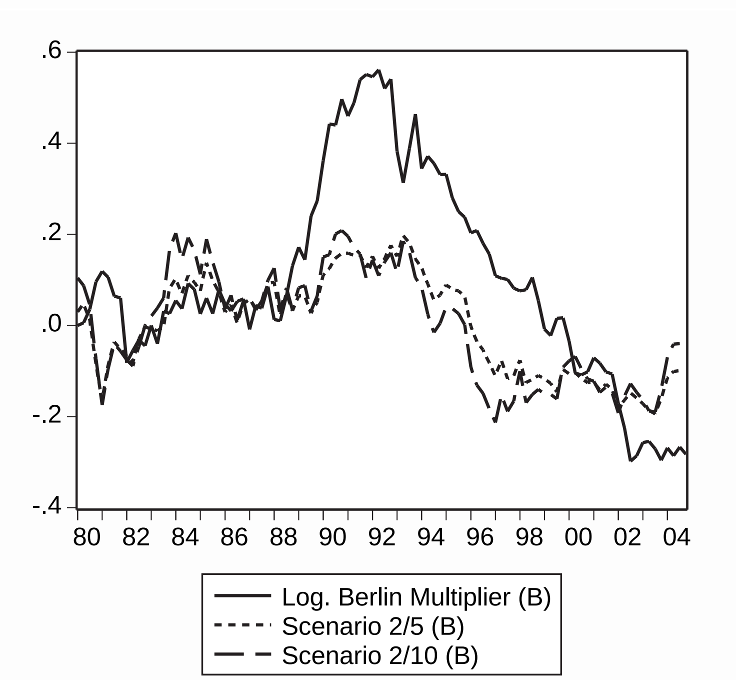


Figure 7: Selected impulse responses to productivity shock, Scenario 1/5

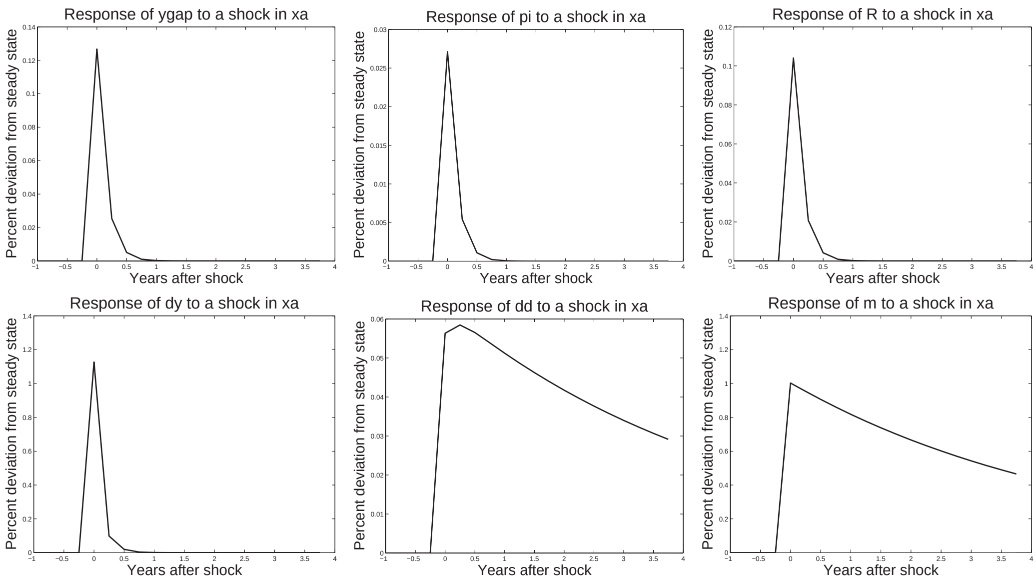


Figure 8: Selected impulse responses to productivity shock, Scenario 2/5

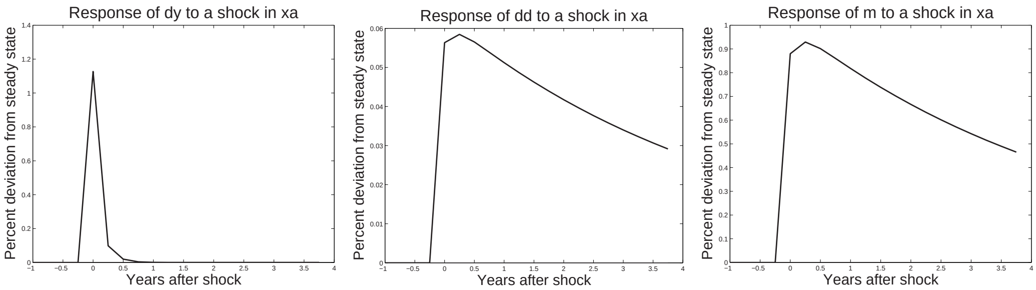


Figure 9: Selected impulse responses to demand shock, Scenario 1/5

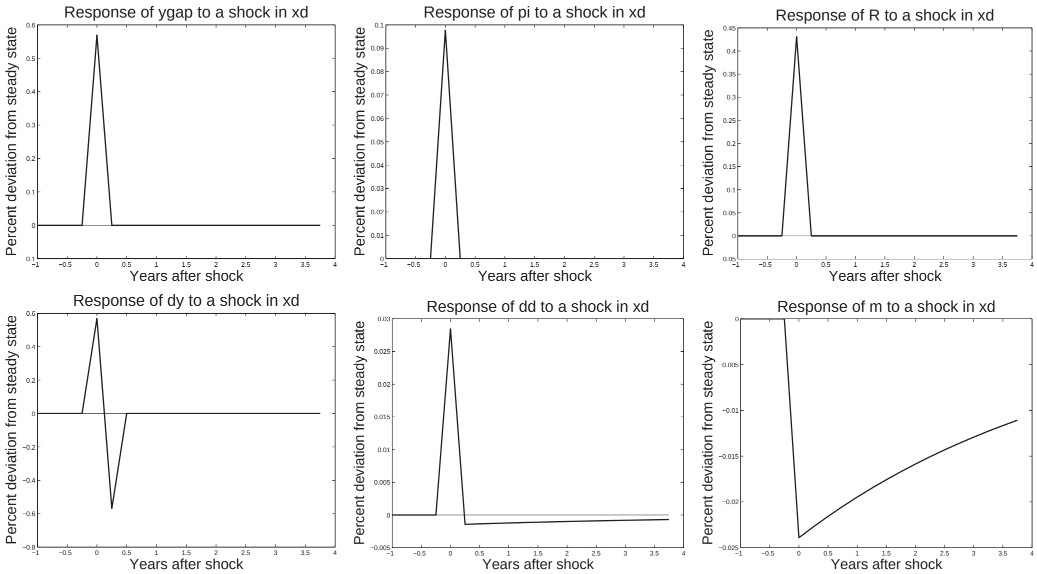


Figure 10: Selected impulse responses to demand shock, Scenario 2/5

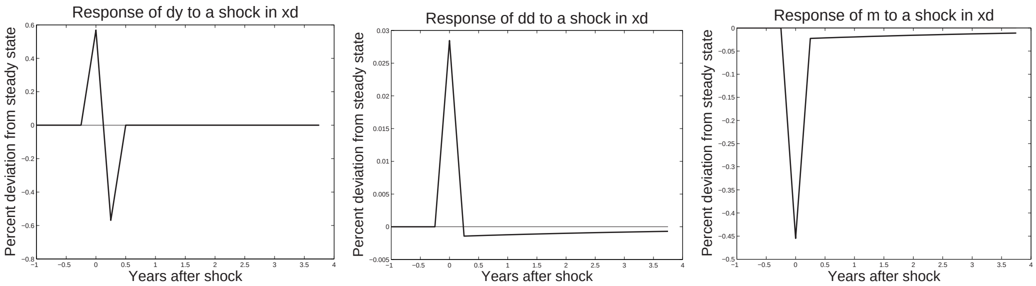


Figure 11: Selected impulse responses to cost push shock, Scenario 1/5

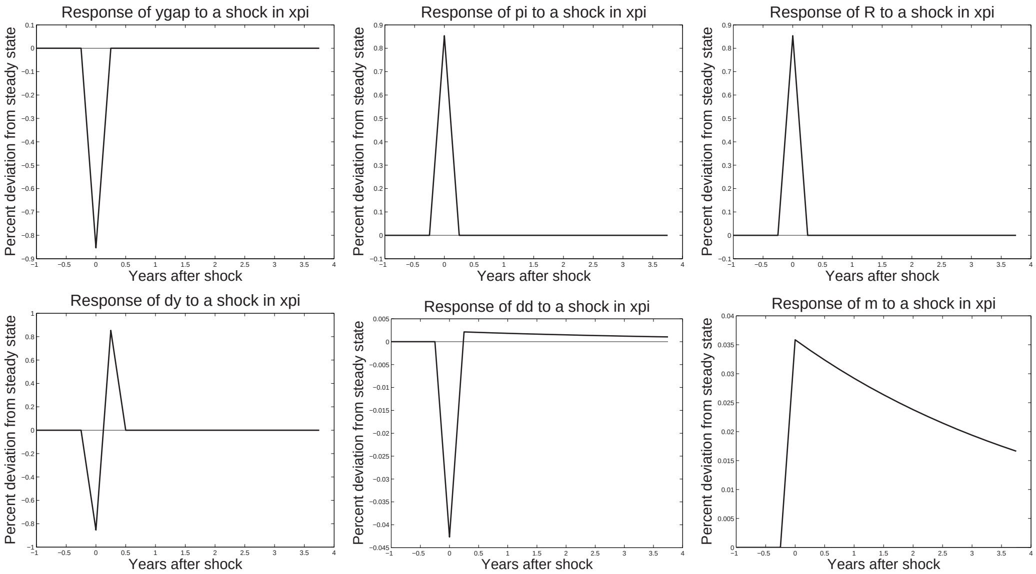


Figure 12: Selected impulse responses to cost push shock, Scenario 2/5

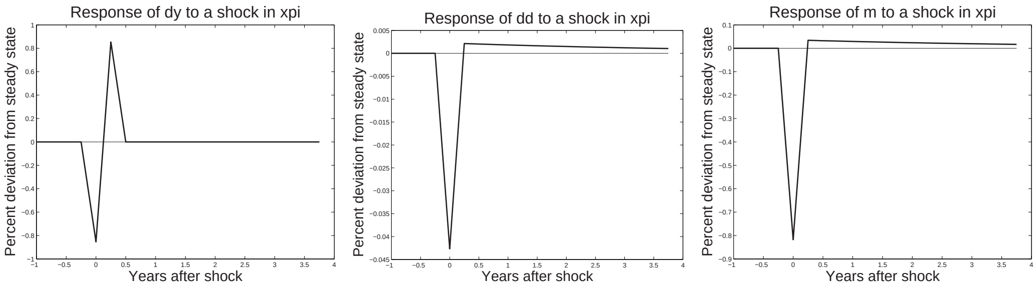


Figure 13: Selected impulse responses to monetary policy shock, Scenario 1/5

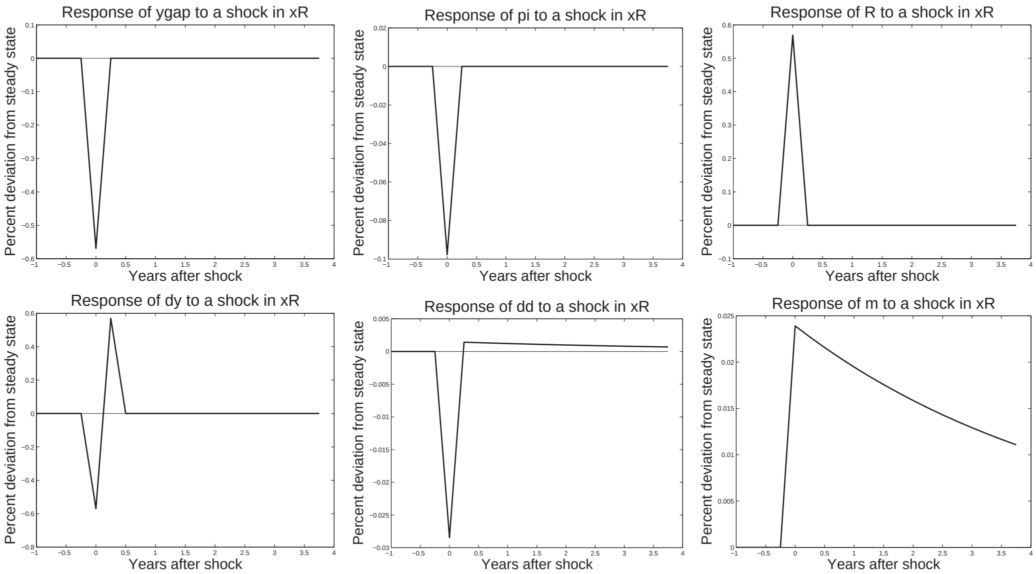
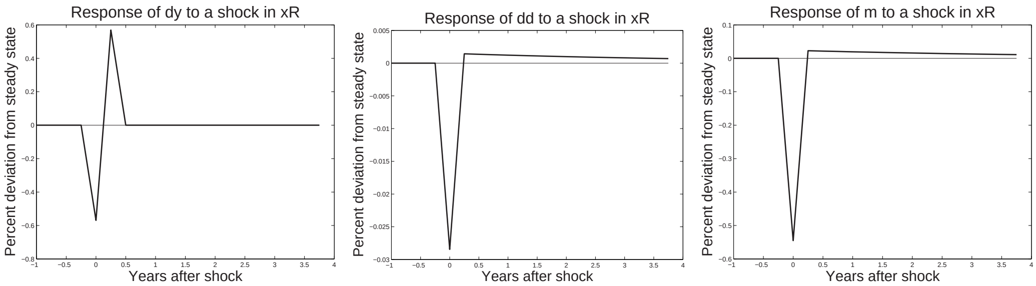


Figure 14: Selected impulse responses to monetary policy shock, Scenario 2/5



List of Tables

Table 2: RVF test statistics, for a detailed description see page 10.

Panel A1: VAR with m_t included, $\alpha = 0.05$		
	Scenario 1	Scenario 2
Non-linear Wald test statistic	11.71	33.44
P-Value	0.16	0.00
Ratio of Std. Deviations, m_t and m_t^*	0.93	2.04
Correlation of m_t and m_t^*	0.84	0.79
Ratio of Std. Deviations, h and h_t^*	0.77	1.42
Correlation of h and h^*	0.44	0.07
Panel A2: VAR with m_t included, $\alpha = 0.1$		
	Scenario 1	Scenario 2
Non-linear Wald test statistic	10.30	24.71
P-Value	0.24	0.00
Ratio of Std. Deviations, m_t and m_t^*	0.82	1.80
Correlation of m_t and m_t^*	0.77	0.62
Ratio of Std. Deviations, h and h_t^*	0.64	1.13
Correlation of h and h^*	0.37	0.11
Panel B1: VAR with m_t excluded, $\alpha = 0.05$		
	Scenario 1	Scenario 2
Ratio of Std. Deviations, m_t and m_t^*	1.22	2.25
Correlation of m_t and m_t^*	0.67	0.73
Ratio of Std. Deviations, h and h_t^*	0.92	1.44
Correlation of h and h^*	0.10	0.07
Panel B2: VAR with m_t excluded, $\alpha = 0.1$		
	Scenario 1	Scenario 2
Ratio of Std. Deviations, m_t and m_t^*	1.11	1.94
Correlation of m_t and m_t^*	0.56	0.56
Ratio of Std. Deviations, h and h_t^*	0.77	1.15
Correlation of h and h^*	0.11	0.11

Notes: α is the smoothing parameter used to compute Δd_t. The two scenarios are for the required return rates. Scenario 1 assumes a constant real required return rate, Scenario 2 assumes a required return rate that consists of the short term risk-free interest rate plus a constant risk premium. The construction of the Wald test ist explained in detail in Appendix A.3. The test can only be conducted when the multiplier is included in the VAR. P-Values are for a $\chi^2(4)$ distribution.

Table 3: Numerical values of the coefficients in the stylized macroeconomic model

σ	β	γ	ϕ_π	ϕ_y	ψ	ρ_a	α
1.0	0.99	0.17	1.5	0.5	1.0	0.2	{0.05,0.1}

Table 4: Theoretical correlations between multiplier and macroeconomic variables

Shock	Supply				Demand				Cost Push				Monetary Policy			
Sc.	1/5	2/5	1/10	2/10	1/5	2/5	1/10	2/10	1/5	2/5	1/10	2/10	1/5	2/5	1/10	2/10
$\tilde{y}$	0.29	0.27	0.39	0.34	−0.12	−0.71	−0.12	−0.82	−0.09	0.94	−0.34	0.92	−0.03	0.90	−0.18	0.89
π	0.17	0.15	0.14	0.16	−0.09	−0.62	−0.07	−0.73	0.10	−0.94	0.35	−0.92	0.03	0.58	−0.08	0.56
R	0.30	0.23	0.35	0.34	-0.11	-0.78	-0.11	-0.88	0.10	-0.94	0.35	-0.93	0.05	-0.90	0.19	-0.89
y^*	0.23	0.25	0.50	0.31	0.74	0.05	0.20	0.15	0.33	0.08	−0.21	0.14	0.46	0.17	0.31	0.12
Δd	1.00	1.00	1.00	1.00	0.37	−0.12	0.42	−0.51	0.34	0.99	0.01	0.99	0.66	0.98	0.34	0.99
r^*	0.36	0.31	0.45	0.43	−0.12	−0.75	−0.12	−0.87	0.10	0.02	0.02	−0.03	0.09	−0.05	0.02	0.04
Δy	0.34	0.32	0.48	0.44	0.05	−0.43	0.08	−0.50	0.03	0.71	0.03	0.70	0.04	0.67	0.06	0.69

Note: The table shows the contemporaneous correlation coefficients of the log multiplier and selected other variables.

Table 5: Empirical correlations between multiplier and macroeconomic variables

	Raw	HP-filtered
π	0.26	0.28
R	0.48	0.55
Δy	0.43	0.33

Notes: The table shows the empirical correlation coefficients of the log. Berlin multiplier and Berlin inflation rate, nominal interest rate and real Berlin GDP Growth, respectively.

Table 6: Summary statistics for transacted apartment houses in Berlin between 1980:1 to 2004:4.

Panel A: Continuous Variables						
	Mean	Median	Std. Dev.	Min	Max	Units
Lot size	1236.5	811.0	2957.6	160.0	68841.0	*Square meters*
Floor space	2240.5	1793.5	3230.8	128.0	89614.0	*Square meters*
Floor-area ratio	2.4	2.4	1.1	0.2	5.9	-
Age	72.8	81.0	29.9	1.0	144.0	*Years*
Price	813.0	511.3	1496.9	34.5	47550.1	*Thsd. EUR*
Real price	983.7	650.9	1678.0	50.5	51666.4	*Thsd. EUR*
Gross rent	57.4	42.2	96.5	3.3	4260.5	*Thsd. EUR*
Real gross rent	72.9	54.7	113.3	4.7	4500.5	*Thsd. EUR*
Gross multiplier	13.5	12.3	5.8	3.6	54.7	-
Net rent	85.3	40.9	199.4	3.8	2583.4	*Thsd. EUR*
Real net rent	85.1	41.0	198.6	3.7	2609.5	*Thsd. EUR*
Net multiplier	14.6	13.5	5.9	5.0	50.3	-
Panel B: Location, Partitition and Social Housing						
Located in East part			13.3%	Condominium		8.9%
Located in redevelopment area			10.9%	Social housing		15.9%
Observations			10382			

Notes: Floor-area ratio is building's floor space dividend by lot size. Age refers to the age at the date of sale. Real prices and rents are expressed in year 2000 Euros and are calculated by dividing nominal figures with the Berlin consumer price index. 9178 observations have information on gross rent and 1204 on net rent. Gross multipliers are price divided by gross rent, net multipliers are price divided by net rent. Condominium indicates if the rented apartments of the house are legally partitioned so that the owner has the right to sell them separately. Social housing indicates if the apartments are rented to entitled low income households at a below market rent.

Table 7: OLS estimates of optimal regression specification for quarterly multipliers from 1980:1 to 1996:1

	Coefficient		t-Statistic	P-Value
Lot size	0.116		14.09	0.000
Floor space	-0.172		-13.71	0.000
Floor space squared	0.032		4.66	0.000
Age	-14.909		-4.97	0.000
Age squared	19.187		5.36	0.000
Gross rent	-0.274		-4.89	0.000
Social housing	0.103		7.71	0.000
Condominium	0.060		5.61	0.000
Redevelopment area	-0.106		-10.99	0.000
Rent regulation	-0.099		-7.26	0.000
		Diagnostics		
R^2	0.563	$\widehat{\sigma}_{\xi}$		0.257
CVS	0.551	Wald-Statistic		1408.423
Observations	8869	P-Value(Wald-Stat.)		0.000

Notes: Dependent variable is the log multiplier $m_{n,t}$. Coefficients for overall constant, quarterly time and district dummies are not reported. The λs of the transformation function given in equation (12) are -0.5 (lot size), -0.5 (floor space) and -2 (age). CVS is computed according to (13). t-Statistics and Wald-Statistic are calculated with heteroskedasticity-robust standard errors. Reported Wald-Statistics is for the null hypothesis that all coefficients in the table are zero, P-Value is for a $\chi^2(10)$ distribution.

Table 8: OLS estimates of optimal regression specification for quarterly multipliers from 1996:1 to 2004:4

	Coefficient		t-Statistic	P-Value
Lot size	0.057		5.45	0.000
Floor space	-0.122		-8.99	0.000
Age	-12.395		-5.15	0.000
Age squared	16.373		5.34	0.000
Gross rent	-0.235		-12.88	0.000
Social housing	0.111		3.82	0.000
Condominium	0.080		2.79	0.005
Simple location	-0.093		-3.97	0.000
Good location	0.084		3.18	0.002
Very good location	0.299		5.95	0.000
Diagnostics				
R^2	0.426	$\widehat{\sigma}_\xi$		0.287
CVS	0.377	Wald-Statistic		404.555
Observations	1540	P-Value(Wald-Stat.)		0.000

Notes: Dependent variable is the log multiplier $m_{n,t}$. Coefficients for overall constant, quarterly time and district dummies are not reported. Average location is excluded location category. The λs of the transformation function given in equation (12) are -0.5 (lot size), 0 (floor space) and -2 (age). CVS is computed according to (13). t-Statistics and Wald-Statistic are calculated with heteroskedasticity-robust standard errors. Reported Wald-Statistics is for the null hypothesis that all coefficients in the table are zero, P-Value is for a $\chi^2(10)$ distribution.