Investor Rationality and House Price Bubbles: Berlin and the German Reunification

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Abstract. We analyze the behavior of investors in the Berlin rental apartment house market over the years 1980-2004. Using constant-quality multipliers (price-rent ratios), we reject the hypothesis that multipliers in the market were set in a rational manner. Supported by narrative evidence, we conjecture that investors misjudged the economic effects of the German reunification. To examine this, we employ a stylized structural economic model and analyze the effects of shocks on rational multipliers. It seems that investors confused the reunification with a permanent supply side shock to the economy. By basing their investment decisions on this misjudgement, investors behaved irrationally, but in a very uncertain and unprecedented environment.

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1 INTRODUCTION

Asset investment means spending money today in the expectation of receiving a stream of income in the future. Given that the income accrues in the future, expected income must be discounted to account for the cost of waiting and the riskiness of the income stream. In the case of rental apartment houses, the future income is rental payments after the deduction of any operating cost. Therefore, one should observe in a given market that investors pay high prices for apartment houses relative to current rents when they expect rents to rise or discount rates to fall in the future.

In forming their expectations, rational investors should have a structural model of the regional economy in mind. This model will take the institutional setting of the respective residential market into account. As long as the economy evolves along a well-understood path, the formation of expectations should be uncomplicated. In the case of an unprecedented event, however, the formation of expectations will be more complicated. Even a slight misjudgement of the consequences of the event can easily lead to investment behavior that will be termed ‘irrational’ in the aftermath.

With hindsight, it is often easy to detect investor misjudgment leading to irrational investment decision. There is ample evidence in the literature of situations where—in retrospect—small events were hyperbolized as justification for unbounded speculation. A recent example was the assertion that the internet will bring an unprecedented age of growth, which fueled the internet stock bubble at the turn of the Millennium (Shiller, 2005). This is now seen by many as a severe misjudgment and a clear case of investor irrationality. There are other events in economic history, however, which were truly unprecedented and their effects difficult to foresee. The fall of the Berlin Wall in 1989 and the subsequent German reunification is an exemplary case of such an event. There was a wide range of professional forecasters’ scenarios for the future development of the German economy and the role of Berlin in it. Most predictions were optimistic, referring to the quick and lasting recovery of West Germany after the end of World War II, for which the expression German miracle (Wirtschaftswunder) was coined. There were also pessimistic predictions of a long, painful, and costly economic recovery process for the East part that would create a burden for the West part of the country.1

In this paper, we study the behavior of investors in the Berlin rental apartment house market during the period 1980 to 2004 using constant-quality multipliers, i.e., price-rent ratios. The multiplier time series allows us to examine investor behavior before and after the fall of the Berlin Wall in 1989. The natural experiment of the reunification makes Berlin, the capital city of the reunited Germany, a particularly interesting market to examine. Further, our paper is the first—to our knowledge—that studies investor behavior in a residential buy-to-let market.2 The paucity of studies might reflect the lack of transaction information because private

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1Collier and Siebert (1991) provide a contemporaneous and balanced account of the different views.
2For reviews on investor rationality in real estate markets, see Cho (1996) for the (owner-occupied) residen-
rental and buy-to-let markets are small in many countries. The size of the rental market in Germany is large in general, specifically so in Berlin, where approximately 90% of the 1.9m residential dwellings are for rent, with 77% of these dwellings in the private market. The coverage of transactions in the Berlin residential market is exceptionally good, providing us with a data set that covers more than 10,000 sales of rental apartment houses. The average house has about twenty separate apartments and a price of about 1m EUR (in year 2000 prices). This unique data set allows the computation of a constant-quality multiplier series, which is based on actual transaction prices.

The results of our paper are as follows. By applying the econometric test for investor rationality introduced by Campbell and Shiller (1987, 1988), we obtain the robust statistical result that multipliers and thus prices were not set in a rational manner. Consequently, we evaluate if the observed irrational multipliers could have been the outcome of a few, but important, misjudgments of investors in the wake of the German reunification. For this evaluation, we use a stylized New Keynesian structural model, in which investors are assumed to be rational and value rental income correctly. By calibrating this model with reasonable parameter values, we find that the observed multiplier behavior can be rationalized if investors made the misjudgement that the reunification was a supply side shock, which would boost productivity in the economy as a whole and Berlin in particular. Rather than a second German miracle, however, the true shock was likely more demand than supply side driven. The shock boosted income temporarily after reunification, but not permanently. In summary, we find that investor behavior in the Berlin residential rental real estate market after the fall of the Berlin Wall and the reunification of Germany was not rational, but deviated from rational behavior in a comprehensible way.

The paper is organized as follows. Section 2 motivates and tests investor rationality. Section 3 compares empirical stylized facts with those generated by the structural model. Section 4 concludes. The Appendix summarizes the time series used in the paper. A Supplement gives further details.

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4Actual transaction prices are hard to obtain, thus most available information on real estate is based on valuations.
5The Supplement is available from Holtemöller's website www.jpeco.rwth-aachen.de.
2 RATIONAL INVESTMENT AND THE BERLIN INVESTMENT

2.1 Motivation

The present value of a rental apartment house is

$$V_t = E_t \left[ \sum_{j=1}^{\infty} \frac{D_{t+j}}{\prod_{k=1}^{j} (1 + H_{t+k})} \right],$$  \hspace{1cm} (1)

which is also the maximum price a rational investor is prepared to pay for the house.\textsuperscript{6} $E_t[\cdot]$ is the conditional expectation operator, $D_{t+j}$ is the net operating rental income of the apartment house in period $t + j$, and $H_{t+j}$ is the required return rate that compensates for waiting and the risk of the rental income. Dividing both sides of (1) with the current net operating rental income leads to the multiplier of an apartment house

$$M_t^* = \frac{V_t}{D_t} = E_t \left[ \sum_{j=1}^{\infty} \frac{\prod_{i=1}^{j} (1 + G_{t+i})}{\prod_{k=1}^{j} (1 + H_{t+k})} \right],$$  \hspace{1cm} (2)

where $G_t = (D_t - D_{t-1})/D_{t-1}$ denotes the growth rate of net rental income. Because $M_t^*$ depends on the unobserved expected future growth and discount rates, the rational multiplier is not directly observable.

Observable multipliers—and cap rates, their inverse—are routinely computed by real estate investors and professional advisors. These multipliers are used to compare different real estate investments and as indicator for the current state of the market. Because a multiplier relates the price to a house’s very own rental income, it considers some of the heterogeneity that is pertinent to all real estate investments. Heterogeneity can be controlled even further with hedonic regression techniques, leading to an observed constant-quality multiplier $M_t$.

If real estate investors are rational on average, then observed transaction prices will be a good indicator of unobservable present values and the constant-quality observed multiplier $M_t$ should be equal to the theoretical $M_t^*$ for the average apartment house investment. As (2) shows, $M_t$ will then be the higher the more future rental income investors expect and the lower their required return rate is. Reasonably, an investor will form expectations on the future rental income and the required return by using some sort of stylized structural model of the regional economy. The model will consider the setting of the interest rate by the monetary authority, which will be an important factor for future regional growth and the return rate of alternative investments. Further, the investor’s model will consider the determination of demand and supply for residential rental space. Demand for residential space will be linked to regional GDP growth through its relation with permanent household

\textsuperscript{6}The right hand side of (1) requires that the house value does not grow forever at a rate larger than the required return rate. Throughout, we assume that this transversality condition is fulfilled.
income. If housing is a normal good, then any increase of permanent income will lead to an increase of the demand for it. If the supply of new rental dwellings is perfectly inelastic, in the short run, the rent per unit of space will increase by an amount to keep demand at its previous level. The resulting increase of rental income accrues completely to existing landlords. If supply reacts with new development and refurbishment, then the increase in rental income for existing apartments will be smaller. Specifically, the elasticity of real rental income for existing houses with respect to permanent household income is

$$\epsilon = \frac{\eta}{\epsilon_D + \epsilon_S},$$

(3)

where \(\eta\) is the income elasticity of the demand for residential space and \(\epsilon_D\) and \(\epsilon_S\) are the rental price elasticities of demand and supply, respectively. Studies on the US rental market have found long-run supply elasticities \(\epsilon_S\) of about 1 and demand elasticities below 1, often with \(\epsilon_D\) smaller than \(\eta\) (de Leeuw, 1971; de Leeuw and Ekanem, 1971; Grieson, 1973; Mayo, 1981). Thus, \(0 < \epsilon \leq 1\) seems reasonable in the long run. In the short run, the rental income elasticity might be above one; this depends on the vacancy rate in existing apartment houses, the ease with which the landlord can increase rents for sitting tenants, and the ease with which new apartments can be constructed.\(^7\)

The return investors require for an apartment house investment has to compensate for the cost of waiting and the inherent risk of the rental income. Taking the risk-free real interest rate as the compensation for waiting, the required return rate will be this interest rate plus a risk premium. We consider two scenarios. Scenario 1 assumes that short-term variations in the real interest rate and the risk premium are negligible: the required rate is effectively constant. Most investors perceive rental real estate—sometimes called ‘concrete gold’ (Betongold)—as steady in terms of the real income it provides and, further, investors often have a long holding period, justifying an approximately constant rate. Scenario 2 assumes a constant risk premium, but allows the real interest rate to vary.\(^8\)

2.2 Qualitative assessment

Figure 1 plots the constant-quality multiplier series \(M_t\) for Berlin apartment houses jointly with the real growth rate of Berlin’s GDP and the German 3-month real interest rate.

[Figure 1 about here.]

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\(^7\)German rent law limits rent increases for sitting tenants to 20% (before 2001 to 30%) over three years. Further, the rent of an apartment must not differ from the rents of comparable apartments. Both aspects do not preclude rent adjustment, but make the process more burdensome. The intention of the law is to prevent rents in old contracts from lagging too much behind new contracts and to guarantee a low dispersion of rents for comparable properties.

\(^8\)We also considered a third scenario in which the risk premium—proxied by the spread between the mortgage and the short term interest rate—is time varying. The empirical results are very similar to the ones for Scenario 1 and are not reported.
Based on an analysis of newspaper and journal articles on the Berlin residential market published between 1987 and 1996, we are able to relate the behavior of the constant-quality multiplier in Figure 1 to events and public opinion. While the multiplier was quite stable during most of the eighties, it rapidly increased at the end of the decade. The most obvious reason for this is the political situation, which resulted in the fall of the Berlin Wall in November 1989 and the process of the German reunification. After the reunification in October 1990, not only was Berlin no longer isolated, in June 1991 it also became the capital city of the reunified country. Many political and economic commentators expected that Berlin would quickly resume the role it had before the Second World War as the industrial powerhouse of mainland Europe. It was predicted by some that Berlin’s population would increase rapidly by 40% to 6m inhabitants.

The multiplier remained high for some time after the reunification, even though it soon became obvious—as the real GDP growth rate in Figure 1 indicates—that hopes of an exceptional economic surge were too optimistic. Moreover, in September 1993, Berlin lost out on hosting the 2000 Olympic Games. Many had speculated this would give the regional economy an additional boost. In 1996, however, commentators were still expecting that the population of the greater Berlin area would increase by 10% during the following decade. Some commentators were concerned that there could be a deficit of rental apartments (Wohnungsnot). But even these projections were overly optimistic and the multiplier reached the pre-reunification level again at the beginning of 2000.

With hindsight, most forecasts of the effects of the reunification were far too optimistic. Although there was a large amount of new investment in the East after reunification, even the current economic situation is gloomy, see Burda (2006) and Uhlig (2006) for recent accounts. The situation in Berlin is certainly better than in many of the East German regions, but the economic development since reunification has lagged behind expectations. Specifically, it is now all too obvious that Berlin could not reconstitute the economic importance it had before 1945.

### 2.3 Testing for investor rationality

To formally examine investor rationality in the Berlin apartment house market, we use the test procedure proposed by Campbell and Shiller (1987, 1988). This procedure computes an approximation of the log rational multiplier series \( m^*_t = \ln M^*_t \) and compares it with the observed log constant-quality multiplier series \( m_t = \ln M_t \). If investors behaved rationally and the further necessary assumptions made are correct, then the two series \( m_t \) and \( m^*_t \) should be statistically indistinguishable; if the series are statistically different, then this leads to the

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9The articles were selected by the press archive team of the Frankfurter Allgemeine Zeitung (FAZ). The selection criteria were: real estate investor expectations, market predictions, price and rent behavior, demand and supply in Berlin’s rental market. Based on these criteria, 48 directly relevant articles were found. These were published in 12 different regional and national newspapers and journals.
conclusion that investors did not invest rationally.

Omitting the constant term, the approximation of the rational log multiplier is

\[
m^*_t = \sum_{j=0}^{\infty} \rho^j E_t[g_{t+1+j}] - \sum_{j=0}^{\infty} \rho^j E_t[h_{t+1+j}],
\]

where \( g_t \equiv \ln(1 + G_t) \), \( h_t \equiv \ln(1 + H_t) \), and \( \rho \equiv \frac{1}{1+\theta} \). \( \theta \) is the long-run equilibrium cap rate, i.e., the inverse of the long-run multiplier.\(^{10}\) As was the case for the untransformed rational multiplier (2), the rational log multiplier \( m^*_t \) (4) will be the higher the higher the expected rental growth rate \( g_t \) and the lower the required return rate \( h_t \).

We implement the test for quarterly data, which requires an estimate of the quarterly \( \rho \). Using the expert-based yearly cap rate of \( \theta = 5\% \), we obtain \( \rho = 0.988.\(^{11}\) To compute the expectation terms in (4), we estimate a reduced form VAR model of the regional economy. The VAR in its VAR(1) companion form is

\[
x_{t+1} = Ax_t + \varepsilon_{t+1}.
\]

The \( 4p \) column vector \( x_t \) consists of the sub-vectors \( \tilde{x}_{t-j}^\top = (m_{t-j}, g_{t-j}, R_{t-j}, \pi_{t-j}) \) with \( j \in \{0, \ldots, p-1\} \), where \( m_t \) is the observed constant-quality multiplier, \( g_t \) the growth rate of real rental income, \( R_t \) the nominal short-term interest rate, and \( \pi_t \) the inflation rate of consumer prices. All series are in mean deviations form. Thus, \( x_t \) includes current and lagged variables that a rational investor would use in a stylized structural model of the economy, i.e., variables that are likely to impact on the growth of the rental income and the required return rate.\(^{12}\) Indeed, (5) can be understood as the—possibly over-fitted—reduced form of a structural model, where the parameters \( a_{ji} \) of the matrix \( A \) are functions of the underlying structural parameters. The only restriction we impose on the reduced form matrix \( A \) is stability. Using (5), the conditional expectation of \( x_t \) is then

\[
E_t[x_{t+1+j}] = A^{j+1} x_t.
\]

The expectation of the \( i \)th variable in \( x_t \) is obtained by multiplying (6) with the column unit vector \( e_i \), which has a 1 in row \( i \) and 0s in all others. The computation of the expectation

\(^{10}\)In the empirical implementation, we work with series in deviations from their respective mean, which justifies the omission of the constant term in the approximation above.

\(^{11}\)This cap rate is recommended in the German Guidelines on Valuation (Wertermittlungsrichtlinien WertR) for income valuation of apartment houses.

\(^{12}\)We have also analyzed VARs with additional variables such as the long-term interest rate. The qualitative findings do not change when additional variables are included.
term for the rental growth rate in (4) is thus
\[ \sum_{j=0}^{\infty} \rho^j E_t[g_{t+1+j}] = e_2^\top A(I - \rho A)^{-1} x_t. \]

However, the required return rate \( h_t \) is not a direct element of \( x_t \). As discussed above, we consider two scenarios: Scenario 1 assumes that the required real return rate is constant and thus zero in deviations form; the second term in the rational multiplier formula (4) is then also zero. In Scenario 1, variation of \( m_t^* \) over time is driven purely by variations in the expected future rental growth. Scenario 2 assumes that the required return equals the risk-free short term real interest rate plus a constant risk premium. In deviations form, the constant risk premium cancels out and the required return rate is \( R_t - \pi_t \). In this case, the second term in the rational multiplier formula (4) becomes \( (e_3 - e_4)^\top A(I - \rho A)^{-1} x_t \). In Scenario 2, variation of \( m_t^* \) over time is driven by variations in the expected future rental growth and the required return rate. The rational multipliers for the two scenarios (indicated by the superscript) are

\[ m_t^{*(1)} = e_2^\top A(I - \rho A)^{-1} x_t \quad \text{and} \quad m_t^{*(2)} = (e_2 - e_3 + e_4)^\top A(I - \rho A)^{-1} x_t. \]

Because \( m_t = e_1^\top x_t \), the null hypothesis of rational investors in the Berlin apartment house market becomes

\[ e_1^\top = e_2^\top A(I - \rho A)^{-1} \quad \text{and} \quad e_1^\top = (e_2 - e_3 + e_4)^\top A(I - \rho A)^{-1} \]

for Scenarios 1 and 2, respectively. The null hypothesis is tested with a non-linear Wald test. To implement the test, we must infer the growth rate of rental income \( g_t \), which is not directly observed. We do this by replacing \( g_t \) with a smoothed average over the real GDP quarterly year-on-year growth rate \( \Delta y_t \). This is justified as follows: Households adjust their housing consumption whenever they perceive income changes to be permanent and exponential smoothing is a convenient method to separate transitory shocks from permanent changes. Applied to the GDP growth, we compute the permanent income growth as

\[ \Delta \tilde{y}_t = \alpha \Delta y_t + (1 - \alpha) \Delta \tilde{y}_{t-1}. \]

The impact of permanent income changes on the real rental income depends on the reaction of supply and demand as measured by \( \epsilon \) (3). It follows that \( g_t = \epsilon \Delta \tilde{y}_t \) and after substitution

\[ g_t = \epsilon \alpha \Delta y_t + (1 - \alpha) g_{t-1}. \]

When implementing the test, we treat \( \alpha \) as a free parameter to analyze its effect on the test
outcomes. Admissible \( \alpha \) values lie in the interval \((0, 1)\). To keep the analysis simple, we set the elasticity of real rental income of existing houses with respect to permanent household income to one, i.e., \( \epsilon = 1 \), which falls in the range of reasonable values.

We use ordinary least squares for fitting the VARs to the data, where the VARs differ with respect to rental growth series, i.e., with respect to the \( \alpha \) used to compute this series. The estimated VARs always include \( p = 2 \) lags of \( \tilde{x}_t \).\(^{13}\) The \( \alpha \) that minimizes the Wald statistic is 0.34. The maximal root of the resulting estimated \( A \) matrix of the companion form (5) is less than one, indicating stability.\(^{14}\) Table 1 reports the outcomes of the Wald tests on investor rationality. It also reports the correlation of \( m_t \) with \( m_t^* \) and the ratio of their standard deviations, which in both instances should be equal to one under the null of rational investors. Further, Table 1 presents the same statistics for the observed approximate ex-post one period return rate and the required return rate implied by rational multipliers

\[
h_{t+1} = -m_t + \rho m_{t+1} + g_{t+1} \quad \text{and} \quad h_{t+1}^* = -m_t^* + \rho m_{t+1}^* + g_{t+1}.
\]

Both the correlation of \( h_t \) and \( h_t^* \) and the ratio of their standard deviations should be equal to one (Cuthbertson et al., 1997).

[Table 1 about here.]

The behavior of the different series can also be inspected visually; Figure 2 plots the rational and the observed multipliers.

[Figure 2 about here.]

Both visual inspection and statistical evidence reveal that the theoretical multipliers are poor in explaining the observed series. The Wald test on the equality of theoretical and observed multipliers can be rejected for both scenarios at the standard significance levels. In particular, the large surge of the multipliers in the course of the reunification is at odds with the rational multipliers. Further, the considerable differences in the volatility of the rational and the observed multipliers is striking. Under Scenario 1, the real required return rate stays constant and the rational multiplier shows stronger positive correlation with the observed multiplier series. Under Scenario 2, the rational multiplier hardly changes, because changes in the expected real rental growth rate are counteracted by the concomitant increase of the real interest rate. Because both scenarios assume a constant risk premium, one could object that a time-varying premium, if counter-cyclical, could explain part of the multiplier behavior.

\(^{13}\)This is unanimously indicated by the information criteria according to Akaike, Schwarz, and Hannan-Quinn.

\(^{14}\)The final estimated VAR has a maximum AR root of 0.97, which is close to non-stationarity. In case of non-stationarity, the non-linear Wald test rejects the null hypothesis too often, see Campbell and Shiller (1989). The P-Values of our test statistics are so small, however, that this problem can be addressed by choosing a small nominal significance level.
However, as mentioned in Footnote 8, there is no indication that a time varying premium would alter the results substantially. We conclude from the above test results that investors in the Berlin apartment house market were not rational and paid prices for apartment houses that did not reflect houses’ fundamental value. The comparison between the time series of the rational and the observed multiplier indicates that investors misjudged the likely effects of the German reunification, paying prices that were based on overly optimistic projections of the future development of the Berlin economy. Once investors became aware of their overreaction, it is possible that the correction went too far, resulting in a constant-quality multiplier below its average value in the 1980s.

3 STRUCTURAL ANALYSIS

3.1 Motivation

The German reunification was an exceptional event surrounded by many uncertainties and errors of judgement were likely. It was not clear to investors if the reunification would have a lasting effect on the growth of Berlin or not. A misconception of the real adjustment process could have led to the observed multiplier behavior. In this section, we calibrate a structural model to assess the degree of investor misjudgement. The outcomes of the structural model depend directly on the assumptions about the shocks to the economy. This allows us to evaluate possible combinations of parameter values that would reproduce the observed multiplier series behavior. We then discuss the plausibility of the parameter combinations.

3.2 Stylized facts

Table 2 shows descriptive statistics for the inflation rate, nominal interest rate, multiplier, and GDP growth over the whole sample from 1980 to 2004. The standard deviation of the multiplier is much larger than the standard deviation of the macroeconomic variables, and the multiplier is positively correlated with output growth, the inflation rate, and the interest rate.

[Table 2 about here.]

Splitting the sample into three sub-samples shows that the sub-sample 1980 to 1988 is different from the subsequence sub-samples 1989 to 1997, and 1998 to 2004. Table 2 clearly indicates that multiplier’s standard deviation and the correlation with other variables is not invariant over time. For example, in the 1980 to 1988 period, the standard deviation of the multiplier was substantially lower, and the correlations between the multiplier and the inflation rate and nominal interest rate were negative.
3.3 Dynamics in a stylized macroeconomic model

We model the behavior of the German national economy with a stylized New Keynesian dynamic stochastic general equilibrium model. The model is consistent with optimizing behavior of firms and the representative households and assumes sticky prices. Such models are commonly used to analyze the macroeconomic connections between output, the inflation rate, and the nominal interest rate (King, 2000; Walsh, 2003; Woodford, 2003). The three equation model we use for the national economy follows Galí (2002). The regional Berlin economy is added to the national model with two further equations, leading to a model with five main equations.

The three main equations of the national model cover the relationship between current consumption, real interest rate and future consumption (new IS curve), the relationship between inflation, inflation expectations and output (Phillips curve), and the policy rule of the monetary authority (interest rate rule). We consider two shocks to the national economy, a demand and a productivity shock.\(^\text{15}\) In contrast to the demand shock, which has only a transitory effect, the productivity shock has a permanent effect on the real output of the economy.

We present auxiliary relationships of the model first.\(^\text{16}\) The first auxiliary equation defines the flexible price output

\[
y^*_t = \psi_a a_t + \psi_d x_{dt}. \tag{12}
\]

This would be the output of the national economy if prices were not sticky. \(a_t\) is the technology of the economy, \(x_{dt}\) the transitory demand shock, and \(\psi_a = (1 + \phi/(\sigma + \phi))\) and \(\psi_d = \sigma/(\sigma + \phi)\). The coefficients \(\psi_a\) and \(\psi_d\) are positive, where \(1/\sigma\) is the elasticity of intertemporal substitution and \(1/\phi\) is the elasticity of labor supply of the representative household. The technology follows a random walk process

\[
a_t = a_{t-1} + x_{at}, \quad x_{at} = \rho_a x_{a,t-1} + \varepsilon_{at}, \quad \varepsilon_{at} \sim N(0, \sigma_a^2), \tag{13}
\]

where \(x_{at}\) is the productivity shock, which has a permanent effect on the technology and the flexible price output. The productivity shock is autocorrelated whenever \(\rho_a \neq 0\).

The second auxiliary equation is the aggregate resource constraint of the economy

\[
y_t = c_t + x_{dt}, \quad x_{dt} = \rho_d x_{d,t-1} + \varepsilon_{dt}, \quad \varepsilon_{dt} \sim N(0, \sigma_d^2). \tag{14}
\]

\(y_t\) is the actual output, \(c_t\) is consumption, and \(x_{dt}\) is the demand shock. The demand shock stands for the share of government expenditures, investments, and the current account. The demand shock is autocorrelated whenever \(\rho_d \neq 0\).

\(^{15}\)The model could be extended with cost-push and monetary policy shocks. This would not, however, change the quality of the main results.

\(^{16}\)As before, lower letters indicate variables in natural logs.
The first main equation of the model is the new IS equation
\[
\tilde{y}_t = y_t - y_t^* = -\frac{1}{\sigma} (R_t - E_t[\pi_{t+1}] - rr_t^*) + E_t[\tilde{y}_{t+1}],
\] (15)
which relates the output gap \(\tilde{y}_t\) between the demand-determined actual output and the flexible price output to the one-period nominal interest rate \(R_t\), the inflation rate \(\pi_t\), and the neutral real interest rate \(rr_t^*\). The neutral rate
\[
rr_t^* = \sigma \psi_a \rho_a x_{at} + \sigma (1 - \psi_d) (1 - \rho_d) x_{dt}
\] (16)
is the rate that equalizes \(y_t\) and \(y_t^*\). The neutral real interest rate increases if a demand shock or an autocorrelated productivity shock occurs because both increase current demand relative to current flexible price output.

The second main equation is the New-Keynesian Phillips curve
\[
\pi_t = \gamma_b \pi_{t-1} + (1 - \gamma_b) \beta E_t[\pi_{t+1}] + \kappa \tilde{y}_t,
\] (17)
which models the dynamics of inflation. This equation 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. \(\gamma_b\) is the fraction of backward-looking firms, \(\kappa\) depends on the degree of price stickiness, the discount factor \(\beta\) and the utility function parameters \(\sigma\) and \(\phi\).

The third main equation is the policy rule of the monetary authority. The policy instrument is the nominal interest rate \(R_t\), which is set according to the following rule
\[
R_t = \phi_R R_{t-1} + (1 - \phi_R) (\phi_\pi \pi_t + \phi_y \tilde{y}_t).
\] (18)
The interest rate depends on the lagged interest rate (interest rate smoothing), inflation rate and output gap.\(^17\)

The model described determines the output gap of the national economy, the inflation rate, and the nominal interest rate. Berlin’s regional economy is added to the model with two equations. The first relates the regional Berlin output growth rate \(\Delta y_{B,t}\) to the national output growth\(^18\)
\[
\Delta y_{B,t} = \Delta y_t + x_{B,t}, \quad x_{B,t} = \rho_B x_{B,t-1} + \varepsilon_{B,t}, \quad \varepsilon_{B,t} \sim N(0, \sigma_B^2).
\] (19)
\(x_{B,t}\) is a transitory shock that is autocorrelated whenever \(\rho_B \neq 0\). The second equation is the

\(^17\)It is established in the literature that the interest rate policy by the Deutsche Bundesbank until 1998 and now by the European Central Bank can be roughly described by such a simple interest rate rule, see Clarida and Gertler (1996) for the Bundesbank and Gerdesmeier and Roffia (2004) for the ECB.

\(^18\)The Supplement presents evidence to support this assumed relationship.
rational multiplier relationship (4), which we rewrite as

\[ m_t^* = \rho E_t[m_{t+1}^*] + E_t[g_{t+1}] - E_t[h_{t+1}] . \] (20)

The growth of real rental income is computed as before with the smoothed real Berlin GDP growth

\[ g_t = \alpha \Delta y_{B,t} + (1 - \alpha) g_{t-1} . \] (21)

Any feedback effects from the regional to the national economy are ignored. Further, as in Section 2, we consider two scenarios for the required return rate. Scenario 1 assumes a constant real required return rate and Scenario 2 assumes a required return equal to the risk-free short term interest rate plus a constant risk premium.

### 3.4 Calibration

We calibrate the model for quarterly data and solve it for the recursive law of motion using the toolkit of Uhlig (1999). Table 3 gives the values of the model parameters.

[Table 3 about here.]

Except for \(\alpha\), the values for the structural economic parameters in the upper part of Table 3 are those widely used in the literature. Modifying these structural economic parameters in reasonable ways does not alter the qualitative results of the analysis. The quarterly parameter \(\alpha\) used for the computation of quarterly rental income corresponds to the annual value of 0.34 that has been used in Section 2. The properties of demand and the Berlin growth rate shock are estimated from the data. Following Galí (2002), the demand shock parameters are taken from an estimated AR(1) model for \(-\ln\left\{1 - \frac{(Y_t - C_t)}{Y_t}\right\}\), where \(\frac{(Y_t - C_t)}{Y_t}\) is the share of the components other than consumption in real German GDP. The properties of the Berlin real growth shock follow from an AR(1) model for the difference between German and Berlin real GDP growth (for details, see the Supplement). The moments of the productivity shock cannot be estimated because productivity is not directly observable. We set the standard deviation of the productivity shock to 0.01 and the corresponding AR(1) coefficient to 0.2, values that correspond to those used in the literature.

---

19 There are at least two channels through which the multiplier could influence other macroeconomic variables. First, the monetary authority could have asset prices on its radar and could raise the interest rate if the house price inflation is perceived as being too high. It is, however, not clear if the monetary authority considers asset prices at all in its decision making; even if it considers asset prices, Berlin is only one of several housing markets and direct feedback effects might be negligible. Second, and perhaps more importantly, prices of existing houses will be an important indicator of the contribution of the construction sector to the GDP. Modeling the transmission process from prices to construction can be, however, quite complicated.

20 The quarterly smoothing parameter is \(1 - (1 - \alpha)^{0.25}\), where \(\alpha\) is the smoothing parameter for year-on-year growth rates. Due to this adjustment of the smoothing parameter it is not necessary to explicitly calculate the year-on-year growth rates in the calibrated model.
To assess the effect of the chosen shock parameter values on the behavior of the rational multiplier, we compute impulse response functions (given in the Supplement). The impulse response analysis indicates that the correlation between the multiplier and the nominal interest rate reaction to economic shocks depends on the nature of the shock. After an autocorrelated productivity shock, both the nominal interest rate and the multiplier increase. After a positive productivity shock, households expect 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. Given that 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. The initial reaction of the multiplier is slightly larger in Scenario 1 than in Scenario 2. In Scenario 2, the positive effect of future expected GDP and rent growth is partially offset by the negative effect of the nominal interest rate on the discount factor. 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. However, the situation is different in the case of a demand shock. A demand shock is 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 when the demand shock occurs and thus the multiplier decreases. The effect is larger in Scenario 2, where the discount factor increases due to the increase in the nominal interest rate in response to the positive output gap.

3.5 Shock properties and stylized facts

We now turn to the impact of the productivity shock parameters on the statistical properties of the multiplier.

[Table 4 about here.]

As the upper panel of Table 4 shows, the baseline scenario can replicate neither the strong positive correlation between the multiplier and nominal interest rate nor the large volatility of the multiplier. If demand and Berlin-specific shocks are absent, however, we obtain a positive correlation between multiplier and nominal interest rate, thus the correlation between the multiplier and the macroeconomic variables depends on the nature of the economic shocks present. This effect is represented in Figures 3 to 5, where we hold standard deviations and autoregressive coefficients of the demand and Berlin-specific shocks constant while allowing the standard deviation and autoregressive coefficient of the productivity shock to vary. Figure 3 shows the contemporaneous correlation between the multiplier and the real growth rate and between the multiplier and the nominal interest rate. While the multiplier is always positively
correlated with real GDP growth, the sign of the correlation between the multiplier and the nominal interest rate depends on the persistence and standard deviation of the productivity shock. The higher the persistence and the larger the standard deviation, the larger is the correlation of multiplier and nominal interest rate; the correlation can eventually be positive.

Figure 3 about here.

Figure 4 shows the persistence of the multiplier and the relative standard deviation of the multiplier compared with the standard deviation of real GDP growth. The persistence of the multiplier is relatively high due to the persistence of the demand shock and interest rate smoothing. The relative standard deviation increases with the persistence of the productivity shock. The higher the autocorrelation of the productivity shock, the larger is its impact on the multiplier because prices increase more if investors expect that the growth rate will be relatively high for a long period.

Figure 4 about here.

Finally, the standard deviation of the multiplier relative to the real Berlin GDP growth rate also depends on the persistence of the Berlin-specific growth shock, see Figure 5.

Figure 5 about here.

The analysis shows that the behavior of the rational multiplier is sensitive to the parametrization of the economic shocks. Variations in shock parameters can lead to largely different behavior. If investors in Berlin apartment houses misjudged the nature of the shock and, for instance, confounded a demand shock with a productivity shock, then the resulting multipliers will not be compatible with rationality. The positive correlation of the Berlin multipliers and the nominal interest rate, see Figure 1, suggests that investors may have thought that productivity shocks were more important and more persistent then they really were.\textsuperscript{21} For example, taking highly persistent productivity and Berlin growth shocks, such as $\rho_a = \rho_b = 0.985$, allows to replicate the large standard deviation ratio of multiplier and real GDP growth in the data (i.e., 25.582 compared to 25.485).

4 CONCLUSIONS

Rational investors try to make the best predictions about the future development of income when they make investment decisions. As long as an economy evolves along a well-understood path, prediction should be uncomplicated. In the case of an unprecedent event,\textsuperscript{21} As pointed out to us by an anonymous referee, the stable German consumption income ratio provides further evidence that the Reunification shock was perceived as permanent. If consumers had perceived the shock of being transitory, they would have increased consumption by less than income, resulting in a declining ratio. For an analysis of the relationship between German consumption, income, and wealth, see Hamburg et al. (2008).
like the fall of the Berlin Wall and the subsequent reunification process, prediction will be much more complicated.

In this paper we have analyzed investor behavior in the Berlin rental apartment house market. By using a structural macroeconomic model, we find evidence that investor behavior could be deemed ‘rational’ under the expectation that the reunification was a productivity shock and that a second German economic miracle was possible. The scenario was that the West would provide the capital and technology and the East well-trained labor force. In conjunction with Berlin’s eminent role before 1945, this scenario figured Berlin as new industrial powerhouse with swiftly increasing population and economic activity. Narrative evidence from newspaper and journal articles indicates that this view might have been popular with real estate investors. With hindsight, however, this scenario was a misjudgement and the prices paid for Berlin residential real estate were not backed by fundamentals.

APPENDIX

This appendix reports the data used in this study. Quarterly growth and inflation rates are computed as the difference between year-on-year log values.

**Berlin gross domestic product:** Berlin gross domestic product (GDP), real and nominal, 1979:1-2004:4. The series for the whole of Berlin (West and East) starts in 1991 and is calculated for 1970 to 1990 using the growth rates of West Berlin GDP. These data have a yearly frequency. Quarterly data were generated with the distribution technique proposed in Chow and Lin (1971), the quarterly GDP for Germany is used as related series. Data source: Statistisches Landesamt Berlin.


**German gross domestic product:** German gross domestic product (GDP), real and nominal, 1979:1-2004:4. The series for Germany starts in 1991 and is calculated for 1970 to 1990 using the growth rates of the West German GDP. Data source: Statistisches Bundesamt.


**Multiplier:** Constant-quality time series of price-rent ratios of existing apartment houses in Berlin computed with hedonic regression techniques, 1980:1-2004:4. The dependent variable is the log price rent ratio of apartment house transactions, explanatory variables include,
among others, the size of the lot, area of floor space, and building age. The raw data set covers 10382 transactions and is provided by Berlin’s real estate surveyor commission (GAA, Gutachterausschuss für Grundstückswerte) out of its transaction data base (AKS, Automatisierte Kaufpreissammlung). \(m_t\) is the series in logs and \(M_t\) is the transformed index series with value 100 in the first quarter of 1980. The Supplement gives a detailed account of the computation of the multiplier series.

**Short-term interest rate:** 3-month money market rate reported by Frankfurt banks, fractions, 1980:1-2004:4. Data source: Deutsche Bundesbank.

**ACKNOWLEDGEMENTS**

We have benefited from comments and suggestions by two anonymous referees, Verity Watson, Martin Wersing, Jürgen Wolters, and participants of sessions at the Annual Congress 2005 of the Verein für Socialpolitik, the ERES 2005 Conference, the AREUEA 2006 Annual Conference, and in seminars at the Universities of Aachen, Aberdeen, Berlin (Freie and Humboldt), and Duisburg-Essen. We thank Markus Paust for able research assistance. The usual disclaimer applies.

**References**


## List of Figures

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Multiplier, GDP growth, and interest rate 1980:1 to 2004:4</td>
<td>20</td>
</tr>
<tr>
<td>2</td>
<td>Theoretical and observed multipliers, 1980:1 to 2004:4</td>
<td>21</td>
</tr>
<tr>
<td>3</td>
<td>Productivity shock properties and correlation</td>
<td>22</td>
</tr>
<tr>
<td>4</td>
<td>Productivity shock properties and persistence</td>
<td>23</td>
</tr>
<tr>
<td>5</td>
<td>Berlin GDP growth shock properties and the multiplier</td>
<td>24</td>
</tr>
</tbody>
</table>
Figure 1: Quarterly multiplier for Berlin apartment houses (right scale), Berlin GDP year-on-year real growth rate and the German 3-month real interest rates (left scale), 1980:1 to 2004:4. Multiplier series is normalized to 100 in 1980:1. The Appendix describes the series in detail.
Figure 2: Theoretical and observed multipliers, $m_t^*$ and $m_t$, for the two scenarios for the required return rates, 1980:1 to 2004:4. 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. All series are normalized to have a mean of one.
Figure 3: Productivity shock properties and correlation of multiplier and macroeconomic variables. $xaar$ denotes the autoregressive coefficient of the productivity AR(1) process and $xasd$ the corresponding innovation’s standard deviation.
Figure 4: Productivity shock properties and persistence and relative standard deviation of multiplier. $xaar$ denotes the autoregressive coefficient of the productivity AR(1) process and $xasd$ the corresponding innovation’s standard deviation.
**Figure 5:** Berlin GDP growth shock properties and relative standard deviation of multiplier. $x_{bear}$ denotes the autoregressive coefficient of the Berlin real growth AR(1) process and $x_{besd}$ the corresponding innovation’s standard deviation.
## List of Tables

1. Tests of investor rationality .................................................. 26  
2. Observed multiplier and macroeconomic variables .................. 27  
3. Parameters in the stylized macroeconomic model .................... 28  
4. Simulated multiplier and macroeconomic variables .................. 29
Table 1: Tests of investor rationality.

<table>
<thead>
<tr>
<th>Rational valuation test statistics</th>
<th>Scenario 1</th>
<th>Scenario 2</th>
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</thead>
<tbody>
<tr>
<td>Wald statistic</td>
<td>62.90</td>
<td>163.52</td>
</tr>
<tr>
<td>P-Value</td>
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<td>0.00</td>
</tr>
<tr>
<td>Correlation of $m_t$ and $m_t^*$</td>
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<td>0.38</td>
</tr>
<tr>
<td>Ratio of Std. $m_t$ and $m_t^*$</td>
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<td>8.16</td>
</tr>
<tr>
<td>Correlation of $h_t$ and $h_t^*$</td>
<td>0.39</td>
<td>0.12</td>
</tr>
<tr>
<td>Ratio of Std. $h_t$ and $h_t^*$</td>
<td>2.04</td>
<td>3.44</td>
</tr>
</tbody>
</table>

Notes: The Wald statistics are computed for the null hypothesis of $m_t = m_t^*$, which imposes non-linear restrictions on the estimated coefficients of the matrix $A$ of the companion form VAR. Scenario 1 refers to the assumption of a constant required real return rate, Scenario 2 refers to required real return rate equal to the real short-term rate of interest plus a constant risk premium, for the corresponding parameter restrictions see the two equations in (8). The Wald statistics is asymptotically $\chi^2(8)$ distributed under the null.
Table 2: Statistical properties of observed multiplier and macroeconomic variables.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td><strong>Full sample, 1980:1-2004:4</strong></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\pi$</td>
<td>0.005</td>
<td>0.581</td>
<td>0.612</td>
<td>0.328</td>
</tr>
<tr>
<td>$R$</td>
<td>0.006</td>
<td>0.716</td>
<td>0.977</td>
<td>0.549</td>
</tr>
<tr>
<td>$\Delta y$</td>
<td>0.009</td>
<td>1.000</td>
<td>0.265</td>
<td>0.271</td>
</tr>
<tr>
<td>$g$</td>
<td>0.004</td>
<td>0.465</td>
<td>0.980</td>
<td>0.746</td>
</tr>
<tr>
<td>$R - \pi$</td>
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<td>0.499</td>
<td>0.489</td>
<td>0.406</td>
</tr>
<tr>
<td>$m$</td>
<td>0.223</td>
<td>25.700</td>
<td>0.978</td>
<td>1.000</td>
</tr>
<tr>
<td>$\pi$</td>
<td>0.006</td>
<td>0.715</td>
<td>0.780</td>
<td>-0.007</td>
</tr>
<tr>
<td>$R$</td>
<td>0.006</td>
<td>0.756</td>
<td>0.960</td>
<td>0.028</td>
</tr>
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<td>0.967</td>
<td>0.832</td>
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<tr>
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<td>0.471</td>
<td>0.410</td>
<td>0.518</td>
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<tr>
<td>$m$</td>
<td>0.149</td>
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<td><strong>1997:1-2004:4</strong></td>
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<td>$\pi$</td>
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<td>-0.039</td>
<td>-0.246</td>
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<td>0.135</td>
<td>27.001</td>
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**Notes:** $\pi$ is the German inflation rate, $R$ the nominal short-term interest rate, $\Delta y$ the Berlin real GDP growth rate, $g$ the growth rate of real rental income, $R - \pi$ the ex-post real interest rate, and $m$ the observed log multipliers. Calculated statistics are the standard deviation (Std.), the standard deviation relative to the real GDP growth rate (Rel Std.), the first order autocorrelation coefficient (Autocorr.), and the contemporaneous correlation coefficient (Corr.).
Table 3: Values of the parameters in the macroeconomic model.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<td><strong>Structural Economic Parameters</strong></td>
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<td>$\sigma$</td>
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<td>$\varphi$</td>
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<tr>
<td>$\gamma_b$</td>
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</tr>
<tr>
<td>$\kappa$</td>
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<tr>
<td>$\phi_R$</td>
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<tr>
<td>$\phi_{\pi}$</td>
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<tr>
<td>$\phi_y$</td>
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<td>$\alpha$</td>
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<td><strong>Shock Parameters</strong></td>
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<td>$\rho_a$</td>
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</tr>
<tr>
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<tr>
<td>$\rho_d$</td>
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<tr>
<td>$\sigma_d$</td>
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</tr>
<tr>
<td>$\rho_B$</td>
<td>0.300</td>
</tr>
<tr>
<td>$\sigma_B$</td>
<td>0.006</td>
</tr>
</tbody>
</table>
Table 4: Statistical properties of simulated multiplier and macroeconomic variables.

<table>
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<th></th>
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<td>Baseline Scenario</td>
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<tr>
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<tr>
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<tr>
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<tr>
<td>$R - \pi$</td>
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<tr>
<td>$m^*$</td>
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<tr>
<td>Only Productivity Shocks</td>
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<tr>
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<tr>
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<td>0.476</td>
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<tr>
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<tr>
<td>$\Delta y_B$</td>
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<tr>
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<tr>
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<tr>
<td>$m^*$</td>
<td>0.003</td>
<td>0.338</td>
<td>0.971</td>
<td>1.000</td>
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</table>

Notes: Entries show the standard deviation (Std.), relative standard deviations compared to real GDP growth rate (Rel. Std.), the first order autocorrelation coefficient (Autocorr.), and the contemporaneous correlation coefficients (Corr.) of the rational log multiplier $m^*$ with the German inflation rate $\pi$, the nominal interest rate $R$, the real Berlin GDP growth rate $\Delta y_B$, the real rent growth rate $g$, and the ex-post real interest rate $R - \pi$, respectively.