TOBIN'S Q THEORY OF INVESTMENT

APPLIED TO THE UNITED STATES

HOUSING MARKET

By

JOSHUA DANIEL FREIMARK

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The members of the Committee appointed to examine the thesis of JOSHUA DANIEL FREIMARK find it satisfactory and recommend that it be accepted.

Mark Gibson, Ph.D. Chair

Tom Marsh Ph.D.

Salvador Ortigueira, Ph.D,

Abstract

There has been little empirical research studying Tobin's Q theory of investment in real estate or housing markets. The dearth of research on this topic may stem from a lack of data and insignificant results. Using aggregate data on single-family housing prices in the United States, this study concludes that Tobin's Q is an effective theoretical model; however, it should be used with caution when applied to housing markets.

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Introduction

In 1969 Tobin introduced the "Q ratio," which stated that the rate of investment should be directly related to the Q ratio, i.e. the value of capital relative to its replacement cost (Tobin, 1969). The Q ratio was originally intended to improve measurements for firm valuations in financial markets by incorporating physical capital into a firm's value. The underpinnings of this theory are straightforward, logical, and useful in other markets according to Tobin, who states of (his theory): "It *[Q ratio]* can be extended to encompass more sectors and more assets depending on the topic under study" (Tobin, 1969).

Tobin's Q theory has not been widely applied to housing markets. The limited research that has been conducted has found the Q ratio to be a significant predictor for residential investment. Jud and Winkler (2003) are the only researchers that have applied Tobin's Q theory to the United States housing market. They attribute the lack of research to scarcity of data for existing housing prices (the numerator for the Q ratio). Their results from a vector autoregression model show the Q ratio to be a significant predictor for residential investment, building permits, and construction starts.[1] In Berlin, Schulz and Werwatz (2008) studied the relationship between housing prices and replacement costs at the micro-level. Their results conclude that an equilibrating relationship exists and that housing prices and replacement costs quickly align after a housing shock.[2] Schulz & Werwatz question Jud & Winkler's 2003 results by stating "The upward trend is puzzling, because there is no reason

[1]The number of housing permits issued, and construction starts are considered to be lagged measures of residential investment.

[2]Using point estimation they find that 60% of a shock to the Q ratio dissipates after four quarters and after two years prices are fully realigned.

why prices of existing and newly constructed houses should deviate". Berg and Berger (2006) studied the Swedish housing market and conclude that there exists a high degree of correlation with the Q ratio and investment, despite inadequate evidence to establish a long-running relationship with an error correction model during one of the two periods studied.[3] A similar result was obtained in Finland by Takala and Tuomala (1990) by estimating a recursive OLS model that found the Q ratio to be a significant predictor for residential investment from 1980-1987, but not from 1972-1980. Overall, the short supply of literature concerning Tobin's Q theory in housing markets have found the Q ratio to be a significant predictor for residential investment. The purpose of this paper is to test whether Tobin's Q theory can serve as an accurate tool to forecast residential investment and to provide new data to the scant body of research[4] applied to this topic in the United States Housing Market.

Following Jud & Winkler's research using quarterly data from 1979 to 2000, the results from an unrestricted VAR(2) model displayed no significance in the Q ratio. After re-basing the Q ratio and expanding the data from 1975 to 2002, a restricted VAR(4) model revealed the Q ratio to be significant in only three out of the nine times it appeared as an independent variable in the equations estimating residential investment, housing starts, and building permits. This paper contributes to current economic literature regarding Tobin's Q theory of investment by providing updated data to Jud & Winkler's 2003 research. Attempting to ascertain the accuracy of Jud & Winkler's research leads to a thorough explanation of why the FHFA existing home index is valued higher than the Census Bureau's price index for new homes in Jud and Winkler's research. Lastly, the two indices that formulate the Q ratio were re-based—providing an alternative measure of Jud & Winkler's Q ratio. This paper is structured in four parts. Part I introduces investment models; Part II describes the data and models used in this paper; Part III summarizes the empirical results; Part IV summarizes the relevant findings and future research possibilities.

[3] Berg and Berger (2006) conclude that there exists a stable long-run relationship for the Q ratio and logarithm of building starts during 1993-2003 but not between 1981-1992.

[4] See Jud & Winkler 2003.

Investment Models

2.0.1 *Neoclassical models*

Historically, housing investment theory has been dominated by neoclassical models, which use Jorgenson's neoclassical theory of investment as the baseline standard.[1] Jorgenson's most acclaimed model was introduced in 1963. This model combines the cost of financing, taxes, and depreciation to determine the user cost of capital using a Cobb-Douglas production function to solve for a firm's optimal capital stock. Jorgenson then derives an equation demonstrating that investment is a determinant of a firm's optimal capital stock (Jorgenson, 1963).

Four years later, Jorgenson showed two alternative formulations of his neoclassical theory, both of which are equivalent. The first being a capital accumulation firm that acquires assets in order to provide itself with capital services with the object of maximizing its value, subject to a technology constraint. The latter formulation is a profit maximizing firm, that instead of accumulating assets, rents assets to obtain capital services (Hall and Jorgenson, 1967). Jorgenson shows that if either of the representative firms takes capital and input costs as a given, the user cost of capital could be derived from the production function. Altogether, the focus of Jorgensen's theory is that competitive firms can derive their desired level of capital to the point that marginal product of capital should be equal to the real rental price of capital, which once known, can be used to solve for the optimal level of investment.

[1] *The American Economic Review* credited (Jorgenson, 1963) as one of the top 20 papers published in their journal in the first 100 years (Arrow, Bernheim, Feldstein, McFadden, Poterba, and Solow, 2011).

Jorgenson later suggested improvements to the model, stating: "A derivation of this model incorporating installation costs explicitly with constant returns to scale in both production and installation is obviously much more satisfactory than the original derivation" (Jorgenson, 1972).[2] A major shortcoming of neoclassical models is their allowance for instantaneous variation of capital stock and investment, which is not the case in practice.

2.0.2 *Tobin's Q Adjustment Costs*

Firms generally own capital goods instead of renting them, as in previous neoclassical models. Tobin's Q theory determines the rate of investment by evaluating the ratio of market value over replacement costs for the same physical asset.[3] Instead of incorporating rental costs as in previous models, Tobin's Q specifically accounts for adjustment costs by explicitly including adjustment costs when purchasing capital goods. This adaptation improves Jorgenson's model. Different firms and markets will have various adjustment costs that are unique to the industry in which they operate. If a firm's capital stock consists of machines to produce goods, and they invest in new machinery, adjustment costs would include the price of new machinery, installation, revenue forgone during installation, costs incurred from training employees to use the machines, etc. Typically, adjustment costs in literature are assumed to be convex (Abel and Eberly, 1994). Convex adjustment costs increase with investment, meaning higher investment will result in higher adjustment costs. A difficulty arises with adjustment costs when trying to calculate marginal Q. Marginal Q measures the value of a firm adding one additional unit of capital divided by its replacement cost. Marginal Q is often challenging to calculate, because it involves discounting future streams of income generated from one additional unit of capital over replacement cost. Often, firms lack the means to estimate marginal Q, and

[2]This could be interpreted as Jorgenson acknowledging that Tobin's Q theory is a more satisfactory model because it explicitly accounts for adjustment costs.

[3]Tobin specifically states that Q ratio compares "two valuations on the same physical asset" (Tobin, Brainard, et al., 1976). Despite stating the valuations must be on the same physical asset, Tobin proceeds to compare new and existing homes (through the Q ratio), which shows that his theory can be applied to housing markets.

for this reason, average Q is often used instead. Hayashi (1982) derived an exact relationship between marginal and average Q that shows "If a firm is a price-taker with constant returns in both production and installation, then marginal Q is equal to average Q" (Hayashi, 1982). Hayashi derived an equation demonstrating that marginal Q is equal to average Q. He validated this claim with an OLS regression showing the two ratios are almost identical under these assumptions.[4] This simplifies the calculation for Tobin's Q in the sections that follow, because in the U.S, housing suppliers do not have pricing power. If suppliers try to increase the price of a new home without justification, then consumers will simply purchase a close substitute, an existing house. Hereafter when referring to the "Q ratio," that means average Q ratio, which can be defined as:

$$\frac{\text{Market value}}{\text{Replacement cost}} = \text{Q ratio}$$

Tobin's Q theory states that equilibrium occurs when $Q = 1$. "In equilibrium the volume of construction will meet demands for replacement and normal growth and the size of the stock will be such that market value is the same as marginal production cost for the equilibrium volume of construction (Tobin et al., 1976)." Deviations from equilibrium occur if existing houses (market value) and new housing costs (replacement cost) do not move in tandem. If existing houses increase at a faster rate than new houses, then $Q > 1$. Suppliers are expected to respond to the demands of consumers and dissipate the price gap by building new houses. Suppliers will build more houses, leading to an increase in residential investment. If the opposite occurs and new housing prices increase faster than existing house prices, then $Q < 1$, and suppliers will not see profit opportunity, likely hindering new construction plans.

[4] Hayashi uses aggregate annual data on residential structures, non-residential structures, & durable equipment, which further validates the use of Tobin's Q in the housing market.

2.0.3 *Tobin's Q & Residential Investment*

Housing investment and residential construction are driven by deviations between existing houses and replacement cost. If developers see that existing houses are priced higher than the cost of constructing a new house, then they will look to capitalize on this price discrepancy by developing more houses to increase revenue. This has held true for decades. Even in the 70s, Tobin stated: "An increase in the market valuation of houses relative to the cost of building will encourage construction. The incentive to be made by the excess of market price over replacement cost" (Tobin, Brainard, et al., 1976). Schulz and Werwatz (2008) verify Tobin's suggestion with their findings of an equilibrating relationship between existing housing prices and replacement costs in Berlin. Takala and Tuomala (1990) state that the volume of new housing investment is dependent on the level of housing prices relative to the marginal cost of construction, which is consistent with Tobin's Q theory. Rosenthal (1999) provides an additional factor that drives housing, which he attributes to the price of older buildings depending on past and current values of the relative cost of vacant land to capital. The following sections attempt to affirm the above findings and establish a relationship between existing and new housing prices measured through the Q ratio.

Methodology & Data

For this analysis, two separate groups of data are used. Both data groups are nearly equivalent; however, the second group of variables uses data on investment beginning in 1975. This study begins by introducing the data collected in order to replicate the work done by Jud and Winkler (2003). Investment in single-family structures is published quarterly and was collected from the Bureau of Economic Analysis national income and product accounts (NIPA) and is measured in billions of chained 1996 dollars. Building permits and housing starts were collected from the Census Bureau. They are not seasonally adjusted and are measured in thousands. Housing starts is available annually, quarterly, and monthly, so the quarterly data was used. Housing permits are only available annually and monthly. In-order to convert housing permits from monthly data into quarterly data, three-month observations were summed beginning with Jan, Feb, Mar of 1975.

The denominator for the Q ratio is the price index for new single-family houses, collected from the United States Census Bureau. The data is quarterly, seasonally adjusted, and is available by region as well as nationally in the United States. The index is a Laspeyres type index, designed to express the level of inflation in new house prices and is often referred to as a constant quality type index. It uses the average quantity and prices of a typical 1996 house, which is used as a reference point to show how the average price of houses has changed relative to 1996.[1] This index bases its weight on the stock of owner-occupied houses reported in the Census Bureau in 1996 (Calhoun, 1996). To properly express the Q ratio, the numerator

[1] In layman's terms, the constant quality index expresses the cost in today's dollars for an average US house in 1996.

and the denominator of the Q ratio should have the same base year. Otherwise, the Q ratio will not provide a meaningful or an interpretable value. Both the new and existing price indices are re-based using the following equation.[2]

$$\frac{\text{1996 based index value in 1996}}{\text{1996 based index value in 1975}} = \text{Base year conversion factor} \tag{3.1}$$

The numerator for the Q ratio Jud and Winkler used was collected from the OFHEO, which now operates as the FHFA. The OFHEO was replaced by the FHFA, and fortunately, they continued collecting and publishing data on the existing housing price index. The existing housing price index from the FHFA is equivalent to the data that Jud & Winkler used from the OFHEO, excepting minor data revisions. Jud and Winkler (2003) state that the value of the existing housing index is 91.6 in 1979.1 and 250.8 in 2004.4. This contrasts well with the FHFA existing housing index, which in my data is 91.4 in 1979.1 and 257.61 for 2000.4. These small discrepancies are due to minor revisions in the data. This index is weighted based on owner-occupied housing activity in the 1990 Census population of housing. The index is published as quarterly, non-seasonally adjusted, national data that is also available at the regional level. The data ranges from 1975 to 2019, using repeat sales and refinancings on the same single-family house—hence its title "weighted-repeat sales index." Those five variables were collected to replicate the previous research studying Tobin's Q in the US housing market. As evidenced by the data, re-basing the index changes the value of the Q ratio by about 0.8.[3]

In attempting to replicate the authors' results, it became evident that these two indices should not be compared with one-another. Both indices are derived from a smaller geographical location. Both agencies collect data on smaller locations, which helps in the aggregation of data, which in turn enables the creation of indices for larger locations. First, they compute price indices for each state, then they

[2] The existing housing price index has a base year 1980 so the above equation would substitute 1980 for 1996 to re-base the index.

[3] Re-basing the indices does not insinuate this measurement is the true value of the Q ratio. It is to illustrate the effect of comparing two indices with different base years.

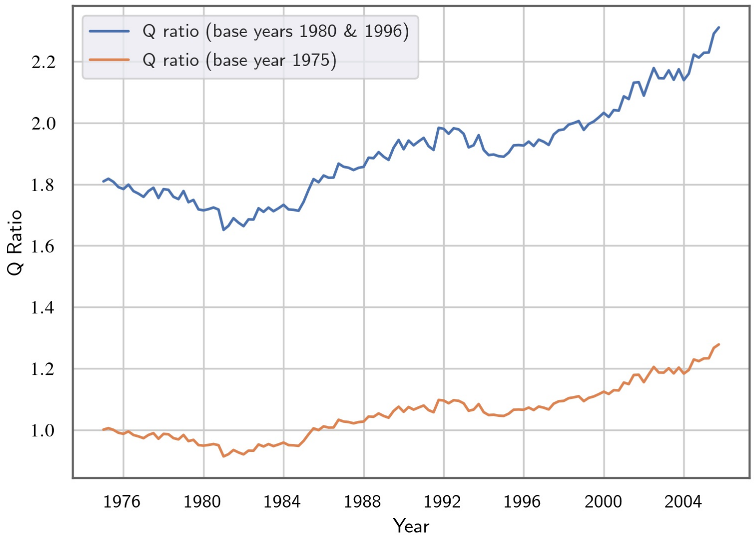

Figure 3.1: Q Ratio re-based to 1975

aggregate the data into larger sub-regions, such as the nine census divisions. From there, they can measure the US aggregate price index. The table below shows the weight given to each region contributing to national price indices.[4]

	HPI Regional Weights	
Region	FHFA	Census
Northeast	8.97%	6.20%
West	19.24%	27.10%
Midwest	26.76%	15.90%
South	34.66%	40.3%

Table 3.1: Sources: Census.gov & FHFA.gov

As evidenced by these calculations, there is a high degree of variation between weights contributing to each region, which signals that these two indices should not be used jointly to conduct meaningful research. Furthermore, the existing HPI only includes detached single-family houses, and the new HPI includes detached as well as attached single-family houses. Attached homes are valued lower, because they tend to be smaller than detached homes.[5] Considering this distinction, it follows

[4]The regional weight percentages sum to 89% due to long form non-response rate of roughly 10% (Hefter and Gbur, 2002).

[5]Structures such as duplexes or townhouses that share a wall with neighbors are considered attached houses.

that the existing HPI is consistently valued higher than the new HPI. The new HPI includes attached houses, lowering the average price of new houses significantly. This synopsis provides an explanation to Schulz and Werwatz (2008) who question Jud & Winkler's 2003 results.

The second group of data in this study was gathered in-order to analyze a complete time period from 1975 to 2002. Vector autoregression (VAR) models require complete observations for each variable included in the model.[6] Jud and Winkler's data began for investment in 1987, and the remaining variables began in 1979; however, reliable observations were available, dating back to 1975. Investment data from the NIPA accounts, measured in billions of dollars, dating from 1975 to 2002 were applied.

In the following section the results from the VAR models will be discussed. VAR models are commonly used for multivariate time-series analysis as they provide a coherent and credible approach to data description, forecasting, and structural inference (Stock and Watson, 2001). It is a dynamic multivariate extension of a univariate autoregressive (AR) model and provides superior results relative to AR models. One favorable characteristic of a VAR model is it's stability; which means that a VAR model can generate stationary time series with time-invariant means, variance, and covariance structure, given sufficient starting values (Pfaff, 2008). A VAR model consists of K endogenous variables $y_t = (y_{1t}, \ldots, y_{kt}, \ldots, y_{Kt})$ for $k = 1, \ldots K$. Every K endogenous variable is modeled with a predetermined number of p lags and is dependent on its own lagged values as well as the lagged values of the other endogenous variables included in the system of equations. The VAR(p) model is defined as:[7]

$$y_t = A_1 y_{t-1} + \cdots + A_p y_{t-p} + CD_t + \mu_t \tag{3.2}$$

[6]Replicating Jud & Winkler's model requires estimating a VAR model for the time period beginning in 1979 and an additional VAR model for the time period beginning in 1987.

[7]Mathematical notation is from Pfaff (2008) & (Lütkepohl, 2005).

Where A_i is a $(K \times K)$ coefficient matrices for $i = 1, \ldots, p$ and μ_t is a K-dimensional white noise process with time-invariant positive definite covariance matrix as well as $E[\mu_t] = 0$. The matrix C is the coefficient matrix of potentially deterministic regressors with dimensions (K $\times$ M) and D_t is an (M $\times$ 1) column vector containing the regressors such as constant, trend, dummy variables, and seasonally dummy variables.

Each of the univariate time-series plots displays seasonal variations, so seasonal dummy variables were included in the model to adjust for seasonal components. To test for unit roots, the Augmented Dicky-Fuller (ADF) test was employed to each series; the null hypothesis cannot be rejected, therefore each series contains a unit root and are deemed non-stationary in levels.[8] The tests were repeated after differencing each series; the null hypothesis is dismissed; therefore, each series does not contain a unit root in first differenced form and are interpreted as difference stationary, integrated order one I(1). By differencing the data, the spurious regression problem is avoided at the expense of reducing the implications that could be drawn from the long-run relationships between the variables. Information criteria is commonly used to determine the optimal number of lags to include in the model. Since the data is measured quarterly, the maximum number of lags we allow for is eight. Results from Akaike criterion (AIC), Hannan-Quinn criterion (HQ), Akaike's Final Prediction Error criterion (FPE), and Schwarz Criterion (SC) unanimously select lag four as the minimum information criterion. Prior to estimating a VAR model, each series is combined into a matrix to test if cointegration is present. The Johansen test allows for multiple cointegrating relationships to be tested for and the results from the trace and eigen statistics report that cointegration is not present.

[8]R statistical software computes the ADF test with the functions adftest(), adf.test() ADF.test(), ur.df(), and stationary.test(). The latter function was used due to its ability to include drift, trend, and lags in the test.

Results

Replicating the prior research on this topic and location yielded disappointing results. The Q ratio did not prove significant following Jud and Winkler's analysis. Lagged permits issued and housing starts had much stronger statistical significance for estimating investment. The Q ratio was only a significant regressor in three of the nine times that it appeared in the variables under consideration in the restricted VAR(4) model using the data set starting in 1975. These results validated the hypothesis that the existing and new housing indices should be re-based to obtain meaningful results. Prior to re-basing the indices the Q ratio showed no significance in the VAR(2) model. Post re-basing the indices and allowing for four lags, the Q ratio was significant three times in the VAR(4) model. The VAR(4) stability can be analyzed through the companion form VAR. The moduli of the eigenvalues of A are less than one, which means that the model is stable. The Portmanteau tests reveals that autocorrelation is present and there is not a white noise process. The results obtained by Jud & Winkler are negligible due to different weights and base years in the indices. Tobin's Q can be measured greater than one if the indices used to create the Q ratio are compiled of unequal weights. That explains why the Q ratio is larger than one. This analysis, however, does not invalidate Tobin's Q theory. Under certain circumstances, a Q ratio greater then one in the housing market is attainable, just not consistently over a long time period.[1]

[1] The authors find the Q ratio to be much larger than one for more than 20 years in the US housing market.

Table 4.1: Restricted VAR(4) using re-based Q ratio with complete obs.

	Measures of Investment		
	Investment	Permits	Starts
ΔQ_{t-1}	-42.040		88.490
	(35.236)		(82.111)
ΔQ_{t-2}	68.203*		
	(35.115)		
ΔQ_{t-3}		316.459*	
		(172.190)	
ΔQ_{t-4}	77.164**		120.385
	(34.337)		(80.307)
Qtr.1	-17.470***	-104.043***	14.435**
	(3.238)	(15.248)	(6.623)
Qtr.2	-12.485***	-79.538***	
	(2.886)	(15.979)	
Qtr.3		-31.665**	
		(13.644)	
Number of obs.	106	106	106
R^2	0.810	0.851	0.983
Adjusted R^2	0.779	0.837	0.981

Notes: ***Significant at the 1 percent level.
**Significant at the 5 percent level.
*Significant at the 10 percent level.

Figure A.1: Unrestricted VAR(2) replicating Jud & Winkler

	Measures of Investment		
	Investment	Permits	Starts
Constant	0.589	1.063	-0.852
	(0.690)	(1.899)	(0.946)
ΔQ_{t-1}	-14.177	3.768	74.123
	(30.439)	(97.874)	(48.748)
ΔQ_{t-2}	-0.479	-30.878	34.229
	(30.663)	(96.845)	(48.235)
Qtr.1		71.936***	-8.750
		(10.911)	(5.434)
Qtr.2		-33.401*	25.844***
		(16.792)	(8.363)
Qtr.3		-26.937*	10.602
		(15.484)	(7.712)
Number of obs.	51	82	82
R^2	0.345	0.894	0.983
Adjusted R^2	0.288	0.881	0.980

Notes: ***Significant at the 1 percent level.
**Significant at the 5 percent level.
*Significant at the 10 percent level.

Conclusion

In replication, the Q ratio showed no significance in the VAR(2) model. Results for the extended time period which began in 1975 found the Q ratio to be significant three out of the nine times it appeared in the VAR(4) equations. Additionally, Tobin's Q demonstrated the least amount of predictive power among the variables used. Although re-basing the indices helped diagnose one of Jud & Winkler's caveats, two problems with the indices persist (first, being weighted differently in different regions, and second, including different types of houses).These problems are intractable. One possible solution may be to re-weight both the numerator and the denominator for the Q ratio post regional indices solution, so they are equal in regional weights. Another solution would be to use a different index. Zillow and the National Association of Realtors collect data on existing housing prices which could possibly serve as a better measure in the Q ratio. Intuitively, the Q ratio should not be consistently valued higher then one in housing markets. Overall Tobin's Q displayed little significance as a variable for predicting residential investment. Due to the way this study's data was measured, this result was not totally unexpected.

Appendix

Table 1. Descriptive statistics.

	Q Ratio	Building Permits	Housing Starts	Housing Investment
Level variables				
Mean	1.8971	237.3625	264.9284	153.3900
Median	1.9436	237.3000	257.8000	150.4500
Maximum	2.1272	363.8000	386.9000	197.4000
Minimum	1.6552	84.2000	113.6000	103.6000
Standard deviation	0.1339	57.2657	59.7962	21.8800
n	88	88	88	56
1st differences				
Mean	0.0040	0.0471	0.5586	0.7000
Median	0.0034	− 4.7000	− 19.4000	1.4000
Maximum	0.0737	119.2000	160.3000	11.6000
Minimum	− 0.0629	− 111.8000	− 105.2000	− 11.2000
Standard deviation	0.0231	49.0955	61.5125	5.3800
n	87	87	87	56

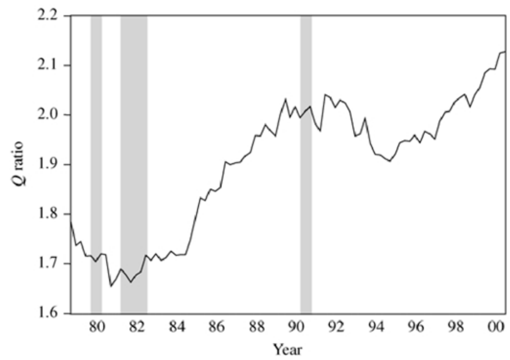

Figure 1. Housing *Q*- ratio from 1980–2000.

Figure A.7: Descriptive statistics replicating Jud & Winkler 2003 research

	Q Ratio	Building Permits	Housing Starts	Residential Investment
Level variables				
Mean	1.8775	237.6818	264.9432	153.4018
Median	1.9084	248.0000	257.5	150.4500
Max	2.1312	358.5000	387	198.0000
Min	1.6516	84.2000	114	103.6000
St. Dev.	0.1172	57.9627	59.7153	21.8998
N	88	88	88	56
1st differences				
Mean	0.0047	−0.1506	0.5517	0.7127
Median	0.0026	0.7000	−20	1.4000
Max	0.0721	80.3000	160	11.6000
Min	−0.0663	−111.8000	−105	−11.2000
St. Dev.	0.0223	51.2251	61.4450	5.3651
N	87	87	87	56

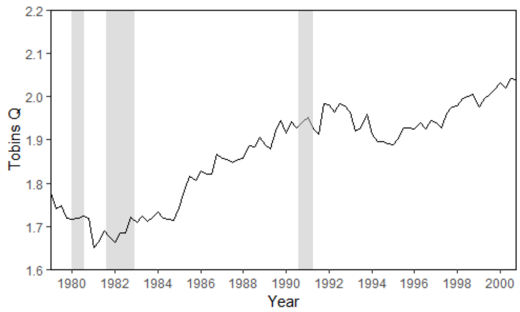

Figure A.6 Replication of Jud & Winkler's time series plot

Figure A.7: Descriptive statistics replicating Jud & Winkler's 2003 research

Table A.5 VAR(4) diagnostics

	Statistic	P-value
Portmanteau	25.79	2.2e-16
ARCH-LM	432.91	0.123
Jarque-Bera	81.01	3.064e-14
Skewness	13.331	0.009
Kurtosis	67.68	7.006e-14

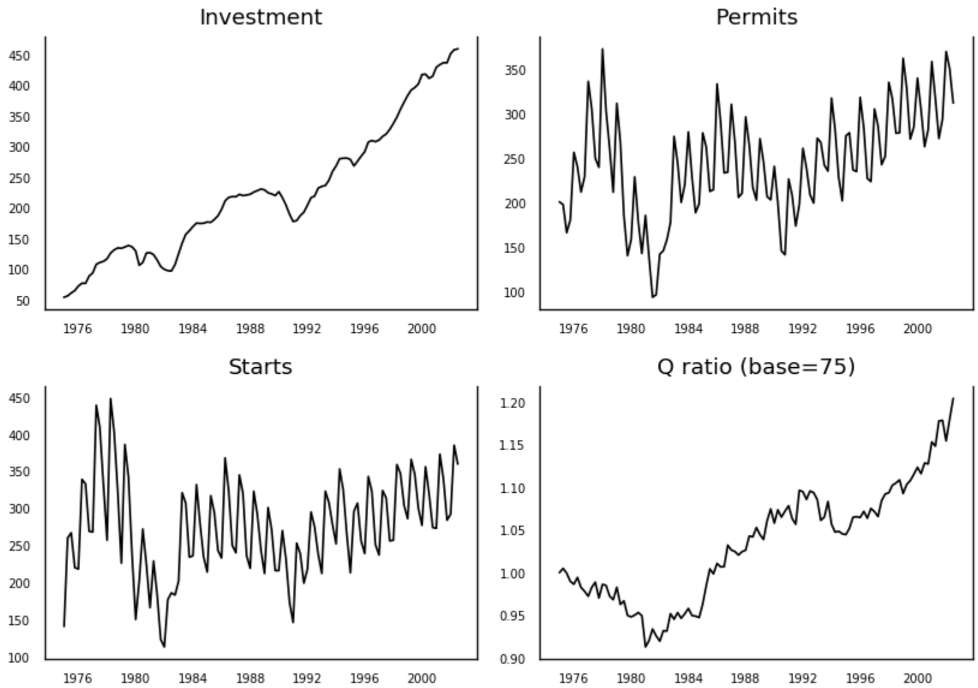

Table A.6 Time series plots for the 1975-2002 time period

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