Demonetized Q: Tobin Meets Jorgenson

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Abstract

I show that the interest rate has a moderating effect on the relation between Tobin's Q and investment. Specifically, including the nominal fed funds rate in the classic investment-Q regression significantly improves the model fit. Equivalently, I construct a novel measure named "demonetized Q", that is, the residual from the projection of the Tobin's Q onto the nominal interest rate. I show that demonetized Q possesses much higher explanatory power for aggregate investment, both in level and in changes and robust across subsamples. Furthermore, I show that demonetized Q captures unique information about investment that bond's Q from Philippon (2009) does not have. In addition, demonetized Q exhibits significantly stronger return predictability than average Q. The nominal fed funds rate could potentially capture stochastic variations in financial conditions or financial constraints that act like "investment wedges" in the sense of Chari, Kehoe, and McGrattan (2007) or "supply shocks" in the framework of Li and Liu (2023).

Keyword: Investment, Q theory, interest rate, monetary policy

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1 Introduction

What drives capital investment? This question has captivated economists across both macroeconomics and corporate finance, inspiring substantial and ongoing theoretical and empirical research efforts. According to Tobin's Q theory, the ratio of market value to replacement costs of capital, or better known as Tobin's Q, is the fundamental drive of investment. According to Jorgenson's neoclassical theory, the user cost of capital-wherein the interest rate plays a central role-is the primary determinant of the optimal level of capital stock. Empirically, however, neither variable seems to possess satisfactorily sufficient explanatory power for investment.

In this paper, I first present a simple theory framework to understand the relation between Tobin's Q theory and Jorgenson's neoclassical theory of investment. I show that Jorgenson's neoclassical theory of investment is a special case of Q theory in which capital is costlessly adjustable. Tobin's Q contains all the information on the optimal level of capital that the user cost of capital does, and both expressions are equivalent. In the case of non-trivial adjustment costs and under constant returns-to-scale, Q is indeed the sufficient statistic for investment and is much more convenient for determining the optimal investment than the user cost of capital. Therefore, the interest rate, when included in the investment-Q regression, should be fully subsumed, in the highly stylized model of investment.

Empirically, however, I show that the interest rate has a moderating effect on the relation between Tobin's Q and investment. Specifically, including the nominal fed funds rate in the classic investment-Q regression significantly improves the model fit. Equivalent, I construct a novel measure named ”demonetized Q”, that is, the residual from the projection of the Tobin's Q onto the nominal interest rate. I show that demonetized Q possesses much higher explanatory power for aggregate investment.

Over the full sample period from 1955 to 2022, Tobin's Q (or average Q) explains about 5 percent of variations in the aggregate investment-to-capital ratio (or the investment rate). When including the nominal fed funds rate, the model fit measured by R^2 increases to 40% from 5%. Adding another interaction term between the nominal fed funds rate and average Q, I find that the response of investment to average Q increases by 0.002 unit for a one-percentage-point increase in the nominal fed funds rate, while the coefficient on average Q is only 0.005 in the univariate regression. Therefore, the nominal fed funds rate has a large moderating effect on the investment-Q relation.

Inspired by these results, I construct a novel measure that aims to exploit information in both the nominal fed funds rate and average Q. I project average Q onto the nominal fed funds rate and collect residuals. I call these residuals "demonetized Q" in the sense that variations in average Q are purged of variations in the nominal fed funds rate, symbolizing monetary policy.

I systematically examine the explanatory power of demonetized Q for investment. First, the demonetized Q explains about 30% of variations in the aggregate investment, compared to 5% by average Q. The coefficient on the demonetized Q triples compared to that on average Q. Second, these improvement are significantly present in HP-filtered trend and cycle components of investments rates and demonetized Q. The explanatory power for investment quintuples for the trend component and triples for the cycle component. Third, the demonetized Q dominates the average Q in explaining the aggregate investment in all three subsamples, 1954-1974, 1975-1994, 1995-2015. The investment-Q relation is modest during 1954-1974, turns even negative during the stagflation period 1975-1994, and becomes strong and tight during 1995-2015. In contrast, the investment-DQ relation is quite strong during 1954-1974, turns smaller and yet remains positive during 1975-1994, and becomes highly strong again during 1995-2015. Fourth, the investment-DQ relation is also significantly stronger than the investment-Q relation in higher frequency. The model fit more than doubles for one-quarter changes and more than triples for four-quarter changes. Finally, I find that bond's Q from Philippon (2009) only explains about 20% of variations in demonetized Q. While bond's Q explains one- third more than demonetized Q (58% vs. 43%), both variables remain significant when using as regressors for investment. Moreover, the R2 increases to 71%, suggesting that the demonetized Q carries unique information that bond's Q does not have. In addition, demonetized Q possesses significantly stronger return predictability than average Q. Stock returns are highly forecastable by demonetized Q over very short horizon even one-quarter and over long horizons, while average Q could predict returns only in 4-year and above horizon.

What could potentially explain the moderating effect of the interest rate on the investment-Q relation? Li and Liu (2023) show that in presence of supply shocks to investment, that are shocks to adjustment costs, investment could be very weakly correlated with average Q or marginal Q. Specifically, the optimal investment rate is a function of both Q and the stochastic adjustment cost. The stochastic adjustment cost could be reinterpreted as stochastic financial conditions or financial constraints, whose variations are largely captured by the level of interest rate. For example, Bolton, Chen, and Wang (2011) shows that the effective marginal cost of investment is the product of the standard marginal cost of investment with convex adjustment costs and the marginal cost of financing. Similar setups are also present in Gomes (2001), Ottonello and Winberry (2020). Importantly, Chari, Kehoe, and McGrattan (2007) show that an economy with credit market frictions as in Bernanke and Gertler (1989) and Carlstrom and Fuerst (1997) is equivalent to a growth model with an time-varying investment wedge, similar to the stochastic adjustment cost in this model. Wang and Wen (2012) show that collateral constraint as in Kiyotaki and Moore (1997) at the firm-level can give rise to the convex adjustment cost at the aggregate level. Given these previous studies, it is theoretically plausible that the nominal fed funds rate captures a large part of variations in financial conditions or financial constraints that act like the stochastic adjustment cost in the generic model of investment.

The remainder of the paper is organized as follows. Section 2 reviews the long literature of Q theory of investment. Section 3 presents a simple theory framework to understand the relation between Tobin's Q theory and Jorgenson's neoclassical theory of investment. Section 4 describes data sources and variables constructions. Section 5 presents and discusses empirical results. Section 6 suggests potential mechanism for the moderating effect of the interest rate. Section 7 concludes.

2 Literature Review

Rooted in thoughts of Keynes (1936)[1], Grunfeld (1960)[2], and Tobin (1969)[3], the Q theory of investment emphasizes the central role of the market value of capital relative to its replacement costs in driving investment decisions. Subsequently formalized by Lucas and Prescott (1971), Mussa (1977), Abel (1979), Yoshikawa (1980), Q-theory says that the optimal rate of investment is such that marginal Q, the ratio of the market value of an additional unit of capital to its replacement cost, equals the marginal cost of investment. Furthermore, Hayashi (1982) shows that, under the condition of constant returns-to-scale technology, marginal Q equals average Q—the ratio of the market value of existing capital to its replacement cost, commonly referred to as Tobin's Q. This equivalence result has deeply influenced the study of both aggregate and corporate investment for more than three decades, despite a long-standing consensus about its empirical limitations.[4]

The disappointing empirical performance of the investment-Q regression has been, under the fundamental view, commonly attributed to the lack of measures of the true marginal Q that is difficult, if not entirely impossible, to be measured empirically. For example, average Q exceeds marginal Q when firms enjoy monopoly rents due to DRS technology or imperfect competition (Lindenberg and Ross (1981)). Average Q fails to capture marginal Q for the specific type of capital when capital goods are heterogeneous and cannot be simply summed up (Hayashi and Inoue (1990)). Average Q overstates marginal Q for physical capital when firm values are derived from intan-

1. Keynes (1936): *For there is no sense in building up a new enterprise at a cost greater than that at which a similar existing enterprise can be purchased; whilst there is an inducement to spend on a new project what may seem an extravagant sum, if it can be floated off on the Stock Exchange at an immediate profit. Thus certain classes of investment are governed by the average expectation of those who deal on the Stock Exchange as revealed in the price of shares, rather than by the genuine expectations of the professional entrepreneur.*

2. Grunfeld (1960): *... that the role of profits (in explaining investment behavior) is probably that of a surrogate variable... there are other variables which reflect these forces better... The principal variable of this type is the "market value of the firm", that is, the value placed upon the firm by the securities markets. When taken in conjunction with an estimate of the replacement value of the physical assets of the firm, this variable appears to be a sensitive indicator of the expectations upon which investment decisions are based.*

3. Tobin (1969): The rate of investment—the speed at which investors wish to increase the capital stock—should be related, if to anything, to q, the value of capital relative to its replacement cost.

4. The disappointing empirical performance is succinctly summarized by Philippon (2009), "The investment equation fits poorly, leaves large unexplained residuals correlated with cash flows, and implies implausible parameters for the adjustment cost function".

gible capital (Hall (2001); Peters and Taylor (2017)). Average Q can also differ from true marginal Q in presence of empirical measurement errors (Erickson and Whited (2000)).

3 Theory

In this section, I show that Tobin's Q theory of investment (in its modern formulation) is compatible with Jorgenson's neoclassic theory of investment. More explicitly, the neoclassic theory of investment is a special case of Q-theory in which there is no capital adjustment costs. Furthermore, under constant returns-to-scale (i.e., satisfying Hayashi's condition), average Q is indeed the sufficient statistic for investment and should fully absorb the effect of the interest rate on investment.

3.1 Static

Consider a firm that uses capital and other (perfectly variables) inputs to produce output. The firm rents capital at a price of r_K. The profit function is given by

$$\Pi = \Pi(A, K) \tag{1}$$

where K is the amount of capital rented and used for production, and A represents all exogenous variables that the firm takes as given. For example, A can include the productivity, the price of output, the cost of labor and/or other inputs. $\Pi(\cdot)$ is assumed to account for whatever optimization that the firm can do on dimensions other than it choice of capital. We further assume that $\Pi(\cdot)_K > 0$ and $\Pi(\cdot)_{KK} \leq 0$. The profit net of rental costs of capital is given by

$$D = \Pi - r_K K \tag{2}$$

The first-order condition for the profit-maximizing choice of capital is given by

$$\frac{\partial \Pi(A,K)}{\partial K} = r_K \tag{3}$$

which implicitly defines the firm's desired capital stock as a function of the rental price r_K and A. It says that the firm rents capital up to the point where its marginal profit of capital equals its rental price.

So, what is the rental price of capital? Most capital is not rented but owned by firms. Thus there is no clear empirical counterpart of r_K. It turns out that we can obtain the answer and the intuition from the dynamic model in which the firm actually owns the capital.

3.2 Dynamic

Consider now the firm owns the capital and choose investment each period to maximize the present value of all profits. The price of capital goods is denoted by P_t.

$$\max_{\{I_t, K_{t+1}\}} \sum_{t=1}^{\infty} \frac{1}{(1+r)^t} [\Pi(A_t, K_t) - P_t I_t]$$
$$s.t. \quad K_{t+1} = (1-\delta)K_t + I_t$$

We can think of the firm's problem as choosing its investment I_t and capital stock K_{t+1} each period subject to the constraint $K_{t+1} = (1-\delta)K_t + I_t$. Since there are infinitely many periods, there are infinitely many constrains of this kind. The Lagrangian for the firm's maximization problem is given by

$$\mathcal{L} = \sum_{t=1}^{\infty} \frac{1}{(1+r)^t} [\Pi(A_t, K_t) - P_t I_t] + \sum_{t=1}^{\infty} \lambda_t [(1-\delta)K_t + I_t - K_{t+1}] \tag{4}$$

where λ_t is the Lagrange multiplier associated with the constraint relating K_t and K_{t+1}. Thus it gives the marginal value of relaxing the constraint; that is, it gives the marginal impact of an exogenous increase in K_t on the lifetime value of the firm's profits discounted to time 0. Alternatively and equivalently, we can define $Q_t \triangleq \lambda_t(1+r)^t$, so that Q_t shows the value to the firm of additional unit of capital at time t in time-t dollars.

$$\mathcal{L} = \sum_{t=1}^{\infty} \frac{1}{(1+r)^t} \left[[\Pi(A_t, K_t) - P_t I_t] + Q_t[(1-\delta)K_t + I_t - K_{t+1}] \right] \tag{5}$$

The first-order condition for the firm's investment I_t in period t is given by

$$\begin{aligned} 0 &= \frac{1}{(1+r)^t}[-P_t + Q_t] = 0 \\ P_t &= Q_t \end{aligned} \tag{6}$$

It says straightforward that the firm invests to the point where the cost of acquired capital goods equals the value of the capital.

The first-order condition for the firm's choice of capital K_{t+1} is given by

$$\begin{aligned} 0 &= -\frac{1}{(1+r)^t} Q_t + \frac{1}{(1+r)^{t+1}} \left[\frac{\partial \Pi_{t+1}}{\partial K_{t+1}} + (1-\delta) Q_{t+1} \right] \\ (1+r)Q_t &= \frac{\partial \Pi_{t+1}}{\partial K_{t+1}} + (1-\delta)Q_{t+1} \\ \frac{\partial \Pi_{t+1}}{\partial K_{t+1}} &= Q_t \left[r + \delta - (1-\delta) \frac{\Delta Q_{t+1}}{Q_t} \right] \end{aligned} \tag{7}$$

Combining both FOCs, we have

$$\frac{\partial \Pi_{t+1}}{\partial K_{t+1}} = P_t \left[r + \delta - (1-\delta) \frac{\Delta P_{t+1}}{P_t} \right] \triangleq r_K \tag{8}$$

It says that the firm invests to the point where the marginal profit of capital equals the shadow user cost of capital, which has three terms. First, the firm forgoes the interest that it would have earned on the proceeds for purchasing the capital. Second, the capital depreciates. Third, the price of capital may change over time, leading to gains or losses in capital goods, but only on the undepreciated part. This is exactly is the user cost of capital that we are looking for.

With expectations, this condition should be

$$(r+\delta)=\mathbb{E}_t\left[\frac{\partial\Pi_{t+1}}{\partial K_{t+1}}\frac{1}{P_t}+(1-\delta)\frac{\Delta P_{t+1}}{P_t}\right] \tag{9}$$

On the right, it is the expected return from investing and using a unit of capital for a period. It is given by the sum of two components: (1) the ratio of the profits of an additional unit of capital to its replacement cost (marginal profit of capital scaled by capital cost); (2) the capital price appreciation on the remaining capital. The expected return from investing and using a unit of capital for a period should in equilibrium equal the interest rate plus the depreciation rate of capital.

If we normalize P_t to be one, then we have

$$(r+\delta)=\mathbb{E}_t\left[\frac{\partial\Pi_{t+1}}{\partial K_{t+1}}\right] \tag{10}$$

Note in this case the numeraire is the investment goods, as a result, profits are in the number of units of investment goods. all variations in capital prices are incorporated in profits.

3.3 Adjustment costs

There are two important observations of this framework so far. First, the firm's problem in the dynamic setting remains static in nature. It is essentially a series of static problems in the dynamic setting, in the sense that investment made in this period would not affect the determination of the optimal level of capital in the next period. Second, firms promptly adjust their level of capital stock to the optimal level given the user cost of capital and the expected profit and capital price change. In the limit of continuous time, the investment rate is unrealistically infinite. In order to make capital adjustment imperfectly adjustable, we introduce the capital adjustment cost. In the words of Lucas (1967), the intent is to build some degree of "capital fixity" in the short-run.

Now let's assume that, in addition to direct purchase costs of new capital goods, it incurs a convex cost of capital adjustment. The adjustment cost is commonly specified as follows.

$$\Phi_t = \Phi(I_t, K_t) = \frac{c}{\eta + 1} IK_t^{\eta+1} K_t \tag{11}$$

where $IK_t \equiv I_t/K_t$ denotes the investment rate, c is a scalar controlling the size of the adjustment cost and η is a curvature parameter controlling the convexity of the adjustment cost.

Now the firm's problem becomes

$$\max_{\{I_t, K_{t+1}\}} \sum_{t=1}^{\infty} \frac{1}{(1+r)^t} \left[\Pi(A_t, K_t) - P_t I_t - \Phi(I_t, K_t) \right]$$
$$s.t. \quad K_{t+1} = (1-\delta)K_t + I_t$$

Two first-order conditions are now given by

$$Q_t = P_t + \frac{\partial \Phi_t}{\partial I_t} \tag{12}$$
$$(1+r)Q_t = \frac{\partial \Pi_{t+1}}{\partial K_{t+1}} - \frac{\partial \Phi_{t+1}}{\partial K_{t+1}} + (1-\delta)Q_{t+1} \tag{13}$$

Combining both, we have

$$P_t + \frac{\partial \Phi_t}{\partial I_t} = \frac{1}{1+r} \left[\frac{\partial \Pi_{t+1}}{\partial K_{t+1}} - \frac{\partial \Phi_{t+1}}{\partial K_{t+1}} + (1-\delta)Q_{t+1} \right] \tag{14}$$

If we think from the perspective of the user cost of capital, the intuition would not be as clear as before.

$$\frac{\partial \Pi_{t+1}}{\partial K_{t+1}} = Q_t \left[r + \delta - (1-\delta)\frac{\Delta Q_{t+1}}{Q_t} + \frac{\partial \Phi_{t+1}}{\partial K_{t+1}} \frac{1}{Q_t} \right] \tag{15}$$

Aside from previous terms, now there is an additional term caused by the adjustment cost, which is the marginal decrease in the next period's adjustment cost given one unit increase in the current capital stock.

However, it is unclear from this equation what the optimal investment should be because the optimal investment in this period would depend on the investment rate in the next period in a recursive manner. This dynamic programming problem in general does not admit analytical solution.

Under constant returns-to-scale, one can show by iterating the condition (14) forward that the RHS equals the ratio of market value to book value of capital, which is exactly the Tobin's Q. That is precisely the ingenious insight of Hayashi (1982). Now we can pin down easily the optimal level of investment by inverting (12). Normalizing the price of capital goods to one, we have

$$
\begin{aligned}
Q_t &= 1 + \frac{\partial \Phi_t}{\partial I_t} = 1 + cIK_t^{\eta} \\
IK_t &= \left(\frac{Q_t - 1}{c} \right)^{\frac{1}{\eta}}
\end{aligned} \tag{16}
$$

In summary, in this highly stylized model of investment with constant returns-to-scale, one can easily pin down the optimal level of investment by observing the Tobin's Q. Tobin's Q fully contains the information of the user cost of capital and extends above and beyond. Therefore, in this model, the interest rate should have no effect on the investment-Q relation.

4 Data and Sample

Now I examine whether the interest rate has a moderating effect on the investment-Q relation empirically. I begin by describing sources of data, construction of variables, and summary statistics.

4.1 Data and variables

I measure the aggregate investment as private nonresidential fixed investment made by nonfinancial corporate business. Data are available at Z.1-Financial Accounts of the United States, prepared by the Federal Reserve. I retrieve the data from FRED by

St.Louis Fed. I also obtain the nominal fed funds rate from FRED. Data are in quarterly frequency, and the sample covers the period from 1955 to 2022.

The investment rate is calculated as the ratio of gross fixed investment to one-period lagged fixed assets. The numerator of investment rates, gross fixed investment, is measured by NFCB gross fixed investment in "non-residential structures, equipment, and intellectual property products (NRSEIP) (FA105013005Q). The denominator is the one-period lagged NFCB nonresidential fixed assets in NRSEIP measured on the basis of current costs (FL105013865Q).

Average Q is calculated as the ratio of the market value of installed capital to the replacement cost of installed capital. The numerator, the market value of NRSEIP, is measured by NFCB market value estimate of nonfinancial assets (FL102010405Q), less nonfinancial assets that are not NRSEIP. NFCB market value estimate of nonfinancial assets (FL102010405Q) is the sum of corporate equities (FL103164103Q), foreign direct investment in U.S (FL103192105Q), total liabilities (FL104190005Q), less total financial assets (FL104090005Q).[5] The denominator, the replacement costs of installed capital, is measured by contemporaneous NFCB nonresidential fixed assets in NRSEIP measured on the basis of current costs (FL105013865Q).

NFCB nonfinancial assets (FL102010005Q) includes real estate at market value (FL105035005Q), equipment, current cost basis (FL105015205Q), nonresidential intellectual property products, current cost basis (FL105013765Q), and inventories excluding IVA, current cost basis (FL105020015). Nonfinancial assets other than NRSEIP includes current costs of inventories excluding IVA (FL105020015Q), current costs of residential equipment (FL105012265Q), market value of residential real estate (FL105035023Q), book value of vacant land (FL105010103Q). I remove components under NFCB nonfinancial assets that are not NRSEIP from NFCB market value estimate of nonfinancial assets.

5. Market values of liabilities can be different from their book values. I do not follow Hall (2001) to adjust for the difference because the resulted adjustment is insignificant in the data provided by Hall (2001).

4.2 Summary Statistics

Table 1 reports summary statistics of investment rates, average Q, nominal fed funds rate, and demonetized Q. The average investment rate is about 11% with a standard deviation of 1.1% over the period 1955-2022. The investment rate is also highly persistent. At the quarterly frequency, the autocorrelation coefficient of the investment rate is 0.97. The mean of average Q is about 1.16 with a standard deviation of 0.48. Average Q is also highly persistent with an autocorrelation coefficient of 0.98. The average nominal fed funds rate is about 4.46% with a standard deviation of 3.39%. The nominal fed funds rate is also highly persistent with an autocorrelation coefficient of 0.97. Among these variables, the investment rate is moderately positively correlated with average Q (0.22) or the nominal fed funds rate (0.31). However, average Q is highly negatively correlated (-0.63) with the nominal fed funds rate, suggesting that the asset valuation is low during periods of high interest rates. The strong correlation between average Q and the nominal fed funds rate implies that there is a large overlap in the information contained by two variables and that extracting the unique information might be empirically interesting and relevant.

5 Main Results

5.1 Investment, Q, and interest rate

First, I show that average Q has poor explanatory power for the aggregate investment. Figure 1 plots both variables in the time series. Three immediate observations appear. First, I observe that the aggregate investment rate exhibits higher-frequency and bumpier movements than average Q, although average Q is more volatile than aggregate investment. Second, consistent with Andrei, Mann, and Moyen (2017), the investment-Q relation is very tight between 1995 and 2015 while it is weak or even negative during 1975-1995. Third, the aggregate investment peaked around 2000 and has since then declined from 14% to 10% in recent years. This is what many researchers call ”declining investment” or ”secular stagnation of investment”.

I regress investment rates in the period t, denoted as IK_t, on the average Q at the beginning of period t, denoted as Q_{t-1}.

$$IK_t = \alpha + \beta Q_{t-1} + \varepsilon_t \tag{17}$$

Results are reported in the first column of Table 2. As commonly reported in the literature, the model fit is very poor ($R^2 = 0.05$) and the coefficient β (0.005) is also trivial.

Second, I show that the nominal fed funds rate also has limited explanatory power, albeit larger than that of average Q, for the aggregate investment. Results are reported in the second column of Table 2. I find that the nominal fed funds rate explains about 11% of variations in the aggregate investment rate and with coefficient of 0.11, high statistically significant at 1%. Their time series are also plotted in Figure 2.

Third, I find that average Q is strongly negatively correlated with the nominal fed funds rate. Their correlation coefficient is about -0.63 from Table 1. From the fourth column of Table 2, I find that the fed funds rate can explain about 38% of variations in average Q. Their correlation is evident in Figure 3.

Fourth, including the nominal fed funds rate in the investment-Q regression significantly improves the model fit. Results are shown in the third column of Table 2. The R^2 increases to 40% from 5% once including the nominal fed funds rate. Both variables remain highly statistically significant. More interestingly, the coefficient on average Q triples.

Fifth, to understand the size of the moderating effect of the nominal fed funds rate, I also include an interaction term between the nominal fed funds rate and average in the fifth column of Table 2. It turns out that the response of investment to average Q increases by 0.002 unit for a one-percentage-point increase in the nominal fed funds rate. Recall that in the first column, the coefficient on average Q is only 0.005 in the univariate regression. Therefore, the moderating effect of the nominal fed funds rate is quite sizable.

5.2 Demonetized Q

Having found out that the nominal fed funds rate has a moderating effect on the investment-Q relation, I construct a novel measure of Q to better forecast investment,

Specifically, I project average Q onto the nominal fed funds rate and collect and name residuals $\varepsilon_{Q,t}$ as "demonetized Q", or simply DQ.

$$Q_t = \alpha + \beta FFR_t + \varepsilon_{Q,t} \tag{18}$$

The demonetized Q is plotted in Figure 4 against the original average Q. The demonetized Q is much bumpier than average Q, after incorporating all the ups and downs of the nominal fed funds rate. From Table 1, I find that the demonetized Q is unsurprisingly highly persistent with an autocorrelation coefficient of 0.96. It by construction has a mean of 0 and a correlation of 0 with the nominal fed funds rate. It remains highly correlated with average Q with a correlation coefficient of 0.78. Moreover, the demonetized Q is strongly correlated with the investment rate with a correlation coefficient of 0.53.

I now systematically examine the explanatory power of demonetized Q for aggregate investment. First, I regress the level of the demonetized Q on the level of the aggregate investment rate. Both variables are plotted in Figure 5. Results are reported in the second column of Table 3. The demonetized Q explains about 30% of variations in the aggregate investment, compared to 5% by average Q. The coefficient on the demonetized Q triples, as in the third column of Table 2. Nevertheless, including the nominal fed funds explains additionally 11% of variations.

Second, I examine both trend and cycle components of investment rates, average Q, and demonetized Q. I apply the HP filter to these variables with a frequency parameter of 1600 for quarterly data. These variables are plotted in Figure 6. Results are reported in Table 4. There is substantial improvement in the explanatory power of both trend and cycle components of demonetized Q over average Q. It quintuples for the trend component and triples for the cycle component.

Third, I re-examine the regression in subsamples. Results are reported in Table 5. The investment-Q relation, shown in Panel A, is modest during 1954-1974, turns even negative during the stagflation period 1975-1994, and becomes strong and tight during 1995-2015. In contrast, the investment-DQ relation, shown in Panel B, is quite strong during 1954-1974, turns smaller and yet remains positive during 1975-1994, and becomes highly tight during 1995-2015. In other words, the demonetized Q dominates the average Q in explaining the aggregate investment in all three subsamples aforementioned. However, notably, both measures fail to account for investment even slightly in the post-2015 period.

Fourth, I examine the investment-DQ relation in higher frequency. Figure 7 plots four-quarter changes in investment rates, average Q, and demonetized Q. Results are reported in Table 6. The investment-DQ relation is also significantly stronger than the investment-Q relation in higher frequency. The R^2 more than doubles for one-quarter changes and more than triples for four-quarter changes.

Fifth, I examine the correlation between the demonetized Q and the bond's Q from Phillppon (2009). One may argue that the is novel measure of demonetized Q could be highly correlated with bond's Q in Phillppon (2009), which is constructed from treasury yields and default rates. I plot the demonetized Q against the bond's Q in Figure 8. Results are reported in Table 7. From the fourth column, I find that bond's Q only explains about 20% of variations in demonetized Q. While bond's Q explains one-third more than demonetized Q (58% vs. 43%), both variables remain significant when using as regressors for investment. Moreover, the R^2 increases to 71%, suggesting that the demonetized Q carries unique information that bond's Q does not have.

In summary, this novel measure demonetized Q has superior explanatory power for aggregate investment in both level and changes and is not subsumed by the well-known bond's Q.

5.3 Return predictability

Similar to the book-to-market ratio or the price-dividend ratio, Q is a valuation ratio that could potentially contains predictive information about future stock returns. I examine this predictive relation empirically and compare average Q and demonetized Q. Results are reported in Table 8. Average Q has very statistically insignificant return predictability over short horizons within 3 years but not for 4-year and 5-year. In contrast, stock returns are highly forecastable by demonetized Q over very short horizon even one-quarter. The R^2 also increases rapidly with the time horizon as expected. Also, including the nominal fed funds rate could boost the return predictability by a limited degree.

6 What does demonetizing do?

What does the projection of Q onto the nominal interest rate actually do? Projecting Q onto the nominal interest rate removes all variations associated with the nominal interest rate in Q. There are two parts: (1) variations that are directly associated with the nominal interest rate; (2) variations in other components of Q that are predictably by the nominal interest rate. I show this result explicitly in this section.

Independent of model specifications, marginal Q_t is given by,

$$Q_t = \frac{X_{t+1} + (1-\delta)Q_{t+1}}{R_{t+1}} \tag{19}$$

where $X_{t+1} \equiv \partial \Pi_{t+1}/\partial K_{t+1}$ is the marginal profit flow in period $t+1$.

Taking log and linearizing, we have

$$q_t \approx \kappa + \rho q_{t+1} + (1-\rho)x_{t+1} - r_{t+1} \tag{20}$$

where $\rho = \frac{(1-\delta)\overline{Q/X}}{1+(1-\delta)\overline{Q/X}}$ is a relative weight depending on the average relative magnitudes of profit and value, and $\overline{Q/X}$ is the point of linearization.

This identity holds for real variables, where Q, X, R are real variables denominated in some numeraire goods. As a convention, the numeraire is the capital good. This identity is closely related to the decomposition by Campbell-Shiller (1988). The only difference is that Q is about the valuation of capital/assets where the PD ratio is related to the valuation of equity. This identity has been previously examined in Cooper et al (2021) on Compustat firms.

Since variables are all real, we use the following identity to introduce the nominal rate. The real return equals the nominal return less the inflation, and the nominal return equals the sum of the excess return and the nominal risk-free rate, that is, $r_{t+1} = r^{\$}_{t+1} - \pi_{t+1} = r_{e,t+1} + r^{\$}_{f,t+1} - \pi_{t+1}$. We have

$$q_t \approx \kappa + \rho q_{t+1} + (1-\rho)x_{t+1} - (r^{\$}_{t+1} - \pi_{t+1}) \tag{21}$$

Iterating this identity forward and assuming the transversality condition holds, i.e., $\lim_{i\to\infty} \rho^i q_{t+i} = 0$, we have

$$q_t \approx const. + (1-\rho)\sum_{i=1}^{\infty}\rho^{i-1}x_{t+i} - \sum_{i=1}^{\infty}\rho^{i-1}r_{t+i} \tag{22}$$

$$= const. + (1-\rho)\sum_{i=1}^{\infty}\rho^{i-1}x_{t+i} - \sum_{i=1}^{\infty}\rho^{i-1}r^{\$}_{t+i} + \sum_{i=1}^{\infty}\rho^{i-1}\pi_{t+i} \tag{23}$$

$$= const. + (1-\rho)\sum_{i=1}^{\infty}\rho^{i-1}x_{t+i} - \sum_{i=1}^{\infty}\rho^{i-1}r_{e,t+i} - \sum_{i=1}^{\infty}\rho^{i-1}r^{\$}_{f,t+i} + \sum_{i=1}^{\infty}\rho^{i-1}\pi_{t+i} \tag{24}$$

Because q_t varies over time, it must forecast profit flow or returns, or both.

Now lets consider a first-order restricted VAR, where the nominal fed funds rate predicts other components in q_t.[6]

$$x_{t+1} = a^x_f + \lambda^x_f r^{\$}_{f,t} + \varepsilon^x_{f,t+1}$$

$$r_{e,t+1} = a^e_f + \lambda^e_f r^{\$}_{f,t} + \varepsilon^e_{f,t+1}$$

$$\pi_{t+1} = a^e_f + \lambda^{\pi}_f r^{\$}_{f,t} + \varepsilon^{\pi}_{f,t+1}$$

$$r^{\$}_{f,t+1} = a_f + \phi_f r^{\$}_{f,t} + \varepsilon_{f,t+1}$$

6. Caution: both x_t and $r_{f,t}$ are highly persistent, the first equation might be subject to spurious regression bias.

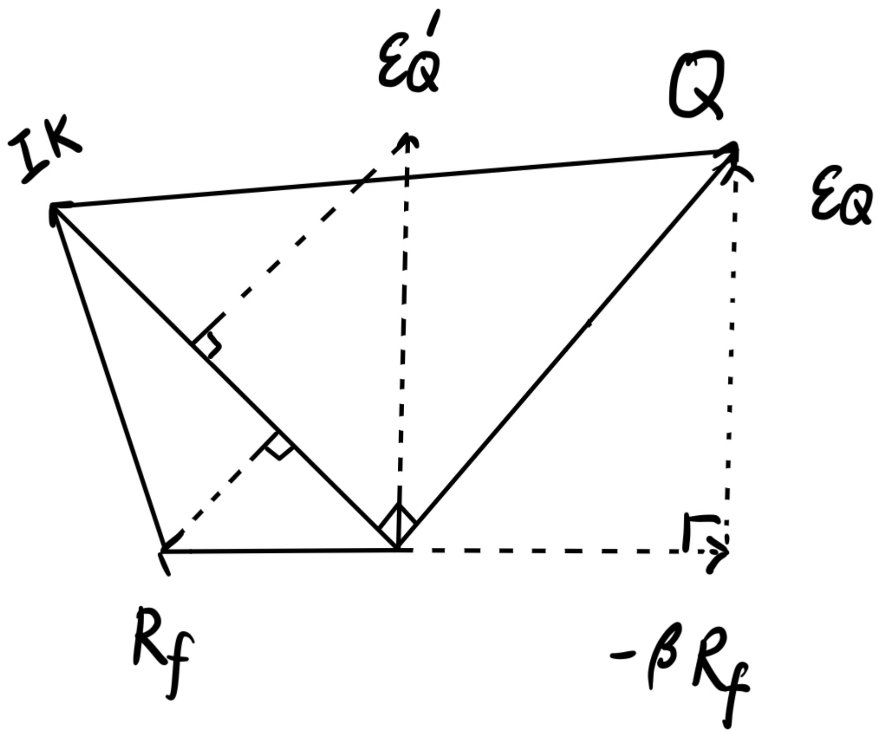
Now we can think of the projection of interest.

$$q_t = a_f^q + \lambda_f^q r_t^f + \varepsilon_{f,t+1}^q$$

Based on the VAR system above, the coefficient on the nominal interest rate should be, up to an approximation error,

$$\lambda_f^q = (1-\rho)\frac{\lambda_f^x}{1-\rho\phi_f} - \frac{\lambda_f^e}{1-\rho\phi_f} - \frac{\phi_f}{1-\rho\phi_f} + \frac{\lambda_f^\pi}{1-\rho\phi_f}$$

Now we see clearly that projecting Q onto short rates removes a persistent component (a geometric series of short rates) plus predictable variations in cash flows, excess returns, and inflations. Residual variations in Q, or demonetized Q, are somehow more informative about investment. To see this visually, I plot a geometric illustration of this decomposition. See below.



In this graph, IK and Q are approximately orthogonal to each other. The nominal interest rate R_f negatively covaries with Q. Residuals ε_Q from the projection of Q onto R_f are now much more positively covary with IK than Q.

This is the puzzle. Why do residual variations in Q, variations that are orthogonal to the nominal interest rate, have much stronger explanatory power for investment?

7 Potential Mechanisms

What could explain the fact that the nominal fed funds rate has a moderating effect on the investment-Q relation and consequently that the demonetized Q has much stronger explanatory power for investment? In this section, I attempt to outline a few possibilities.

First and foremost, when the condition of constant returns-to-scale does not hold, the average Q could be very different from the marginal Q, the true summary statistics for investment under more general conditions. Crouzet and Eberly (2023) show that the difference between the marginal Q and average Q is attributed to 3 components, that are, monopoly rents generated by physical capital, values of intangible capital, and an interaction term measuring rents generated by intangible capital. The nominal fed funds rate captures the difference in a way that picks up omitted variations in the marginal Q. Since marginal Q is not directly observable, this channel could potentially be very hard to test. It is not clear, a priori, how the nominal interest rate is related to these three components.

Second, another possibility is that the nominal fed funds rate picks up a large part of variations in "supply shocks" to investment. Li and Liu (2023) show that in presence of supply shocks to investment, that are shocks to adjustment costs, investment could be very weakly correlated with average Q or marginal Q. In other words, the optimal investment rate is a function of both Q and the time-varying adjustment cost.

$$IK_t = \left(\frac{Q_t - 1}{C_t}\right)^{\frac{1}{\eta}} \tag{25}$$

where C_t denotes the stochastic adjustment cost scalar.

How could the stochastic adjustment cost be related to the interest rate? Bolton, Chen, and Wang (2011) shows that the effective marginal cost of investment is the product of the standard marginal cost of investment with convex adjustment costs and the marginal cost of financing. Similar setups are also present in Gomes (2001), Ottonello and Winberry (2020). Importantly, Chari, Kehoe, and McGrattan (2007) show that an economy with credit market frictions as in Bernanke and Gertler (1989) and Carlstrom and Fuerst (1997) is equivalent to a growth model with an time-varying investment wedge, similar to the stochastic adjustment cost in this model. Wang and Wen (2012) show that collateral constraint as in Kiyotaki and Moore (1997) at the firm-level can give rise to the convex adjustment cost at the aggregate level. Given these previous studies, it is theoretically plausible that the nominal fed funds rate captures a large part of variations in financial conditions or financial constraints that act like the stochastic adjustment cost in the generic model of investment.

8 Conclusion

I show that the interest rate has a moderating effect on the relation between Tobin's Q and investment. Specifically, including the nominal fed funds rate in the classic investment-Q regression significantly improves the model fit. Equivalent, I construct a novel measure named ”demonetized Q”, that is, the residual from the projection of the Tobin's Q onto the nominal interest rate. I show that demonetized Q possesses much higher explanatory power for aggregate investment, both in level and in changes and robust across subsamples. Furthermore, I show that demonetized Q captures unique information about investment that bond's Q from Philippon (2009) does not have. In addition, demonetized Q exhibits significantly stronger return predictability than average Q. The nominal fed funds rate could potentially capture stochastic variations in financial conditions or financial constraints that act like ”investment wedges” in the sense of Chari, Kehoe, and McGrattan (2007) or “supply shocks” in the framework of Li and Liu (2023).

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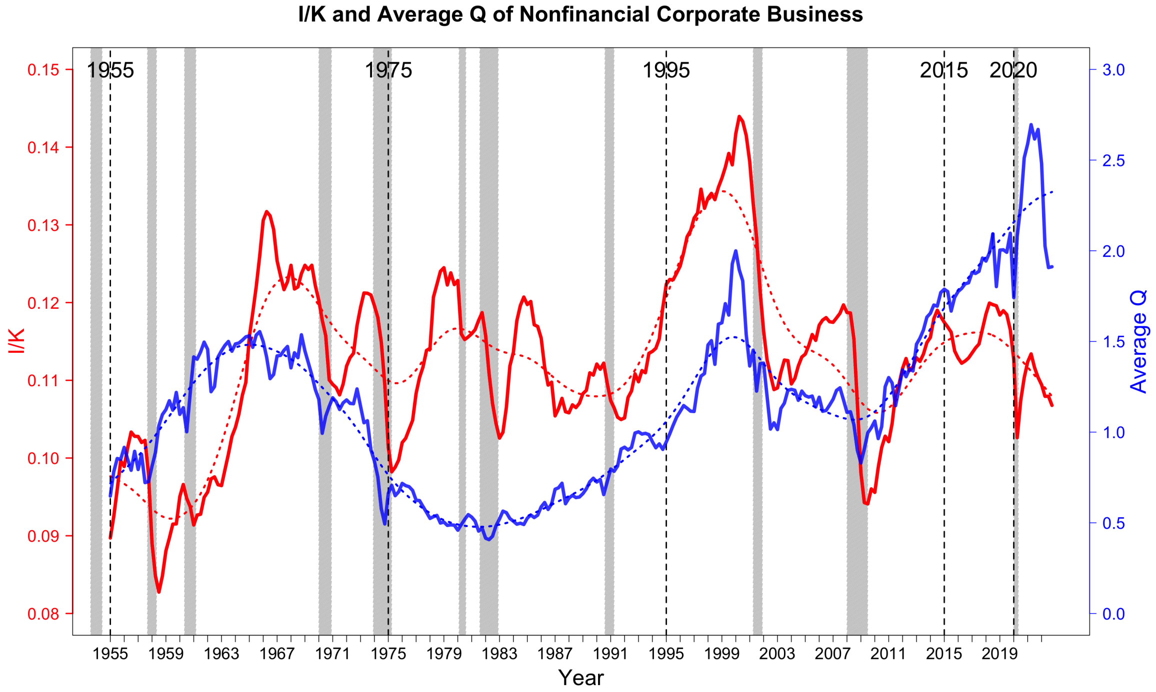
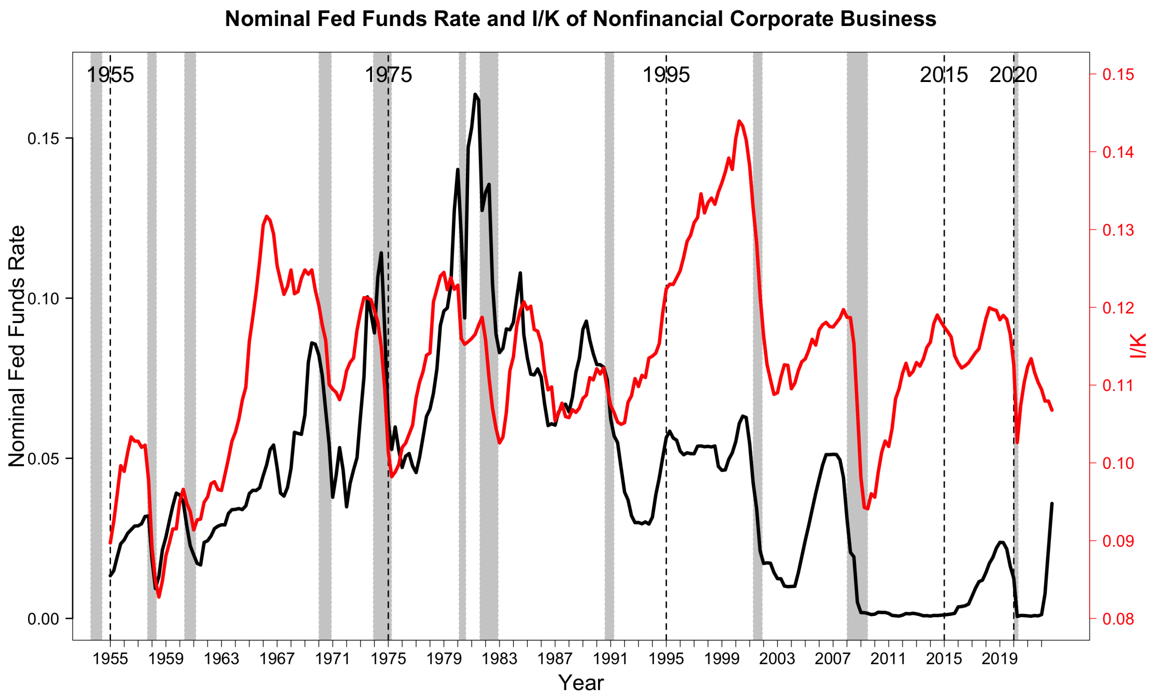
Figure 1: Investment rate and average Q of nonfinancial corporate business



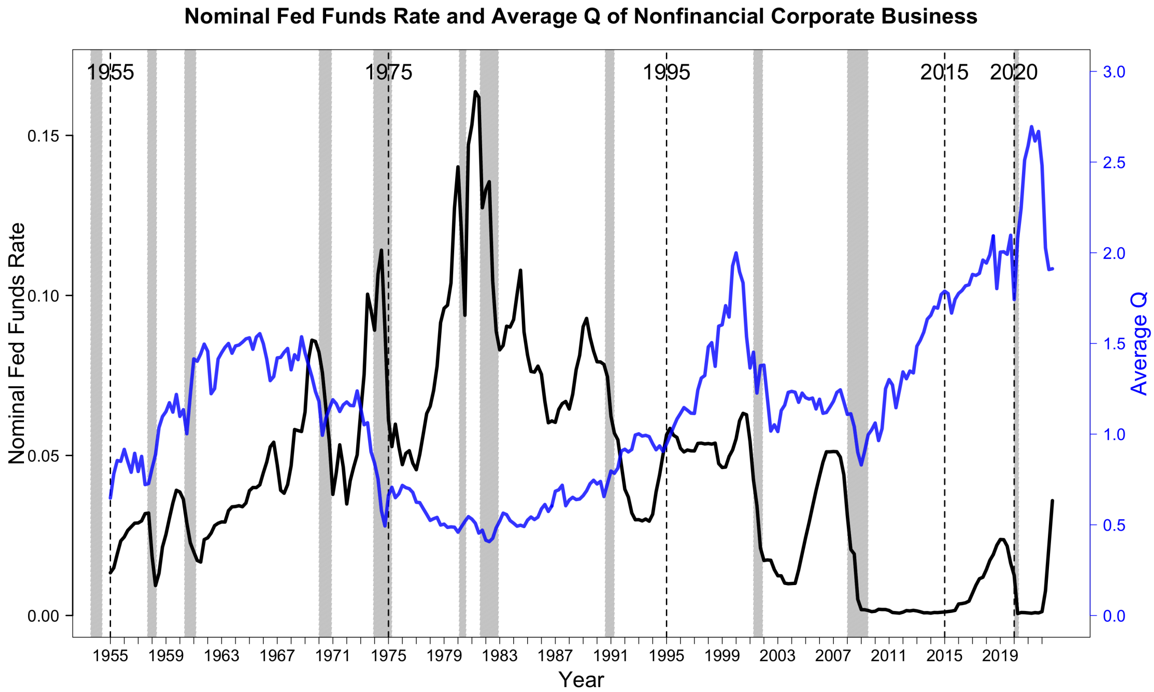
Note: The investment rate is calculated as the ratio of gross fixed investment to one-period lagged fixed assets. The numerator of investment rates, gross fixed investment, is measured by NFCB gross fixed investment in "nonresidential structures, equipment, and intellectual property products (NRSEIP) (FA105013005Q). The denominator is the one-period lagged NFCB nonresidential fixed assets in NRSEIP measured on the basis of current costs (FL105013865Q). Average Q is calculated as the ratio of the market value of installed capital to the replacement cost of installed capital. The numerator, the market value of NRSEIP, is measured by NFCB market value estimate of nonfinancial assets (FL102010405Q), less nonfinancial assets that are not NRSEIP. NFCB market value estimate of nonfinancial assets (FL102010405Q) is the sum of corporate equities (FL103164103Q), foreign direct investment in U.S (FL103192105Q), total liabilities (FL104190005Q), less total financial assets (FL104090005Q). Nonfinancial assets other than NRSEIP includes current costs of inventories excluding IVA (FL105020015Q), current costs of residential equipment (FL105012265Q), market value of residential real estate (FL105035023Q), book value of vacant land (FL105010103Q).NFCB nonfinancial assets (FL102010005Q) includes real estate at market value (FL105035005Q), equipment, current cost basis (FL105015205Q), nonresidential intellectual property products, current cost basis (FL105013765Q), and inventories excluding IVA, current cost basis (FL105020015). We remove components under NFCB nonfinancial assets that are not NRSEIP from NFCB market value estimate of nonfinancial assets. The denominator, the replacement costs of installed capital, is measured by contemporaneous NFCB nonresidential fixed assets in NRSEIP measured on the basis of current costs (FL105013865Q).

Figure 2: Nominal fed funds rate and investment of nonfinancial corporate business



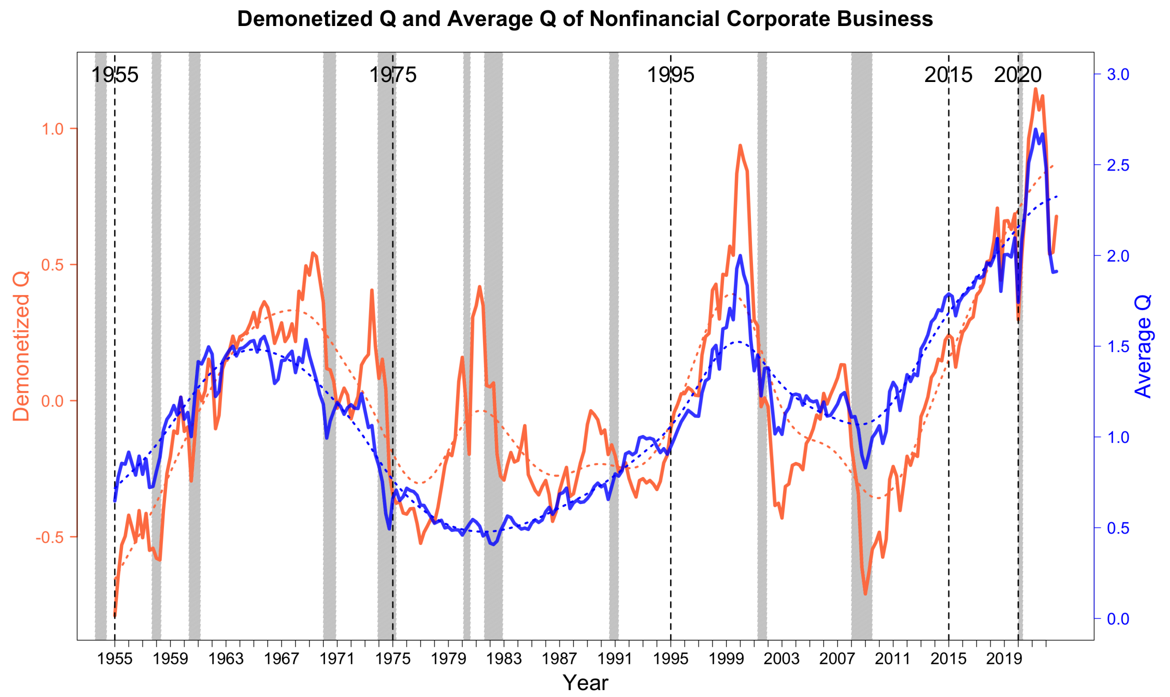
Note: The investment rate is calculated as the ratio of gross fixed investment to one-period lagged fixed assets. The numerator of investment rates, gross fixed investment, is measured by NFCB gross fixed investment in "nonresidential structures, equipment, and intellectual property products (NRSEIP) (FA105013005Q). The denominator is the one-period lagged NFCB nonresidential fixed assets in NRSEIP measured on the basis of current costs (FL105013865Q). The nominal fed funds rate is retrieved from FRED by St.Louis Fed.

Figure 3: Nominal fed funds rate and average Q of nonfinancial corporate business



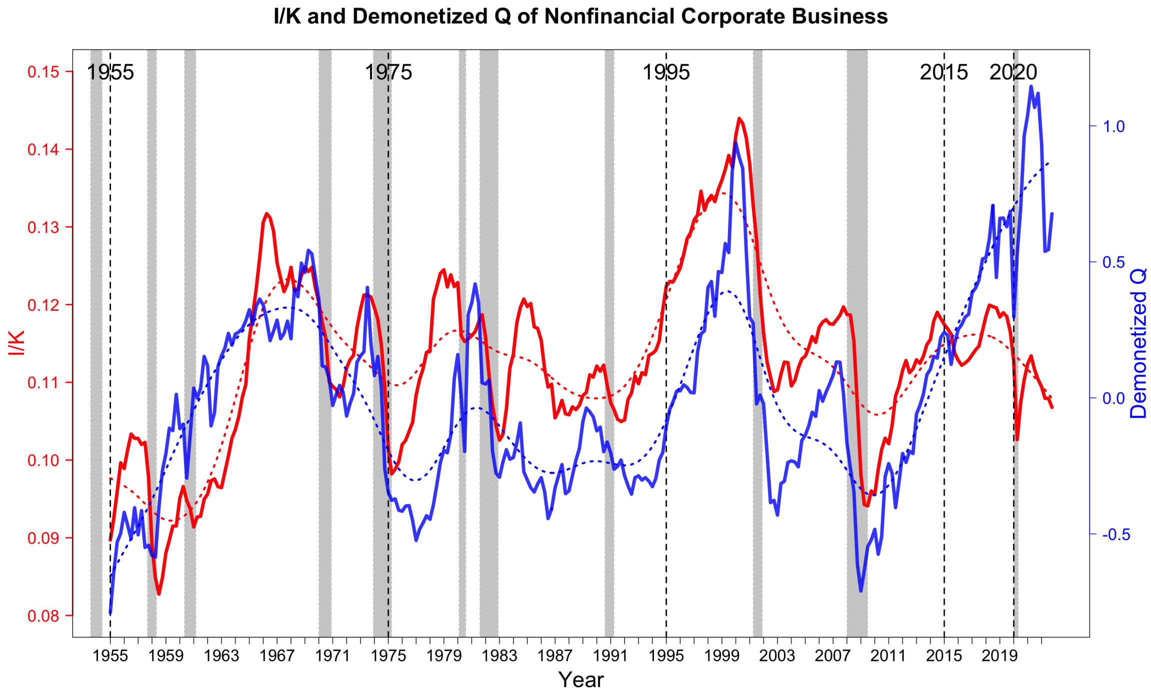
Note: The nominal fed funds rate is retrieved from FRED by St.Louis Fed. Average Q is calculated as the ratio of the market value of installed capital to the replacement cost of installed capital. The numerator, the market value of NRSEIP, is measured by NFCB market value estimate of nonfinancial assets (FL102010405Q), less nonfinancial assets that are not NRSEIP. NFCB market value estimate of nonfinancial assets (FL102010405Q) is the sum of corporate equities (FL103164103Q), foreign direct investment in U.S (FL103192105Q), total liabilities (FL104190005Q), less total financial assets (FL104090005Q). Nonfinancial assets other than NRSEIP includes current costs of inventories excluding IVA (FL105020015Q), current costs of residential equipment (FL105012265Q), market value of residential real estate (FL105035023Q), book value of vacant land (FL105010103Q).NFCB nonfinancial assets (FL102010005Q) includes real estate at market value (FL105035005Q), equipment, current cost basis (FL105015205Q), nonresidential intellectual property products, current cost basis (FL105013765Q), and inventories excluding IVA, current cost basis (FL105020015). We remove components under NFCB nonfinancial assets that are not NRSEIP from NFCB market value estimate of nonfinancial assets. The denominator, the replacement costs of installed capital, is measured by contemporaneous NFCB nonresidential fixed assets in NRSEIP measured on the basis of current costs (FL105013865Q).

Figure 4: Demonetized Q and average Q of nonfinancial corporate business



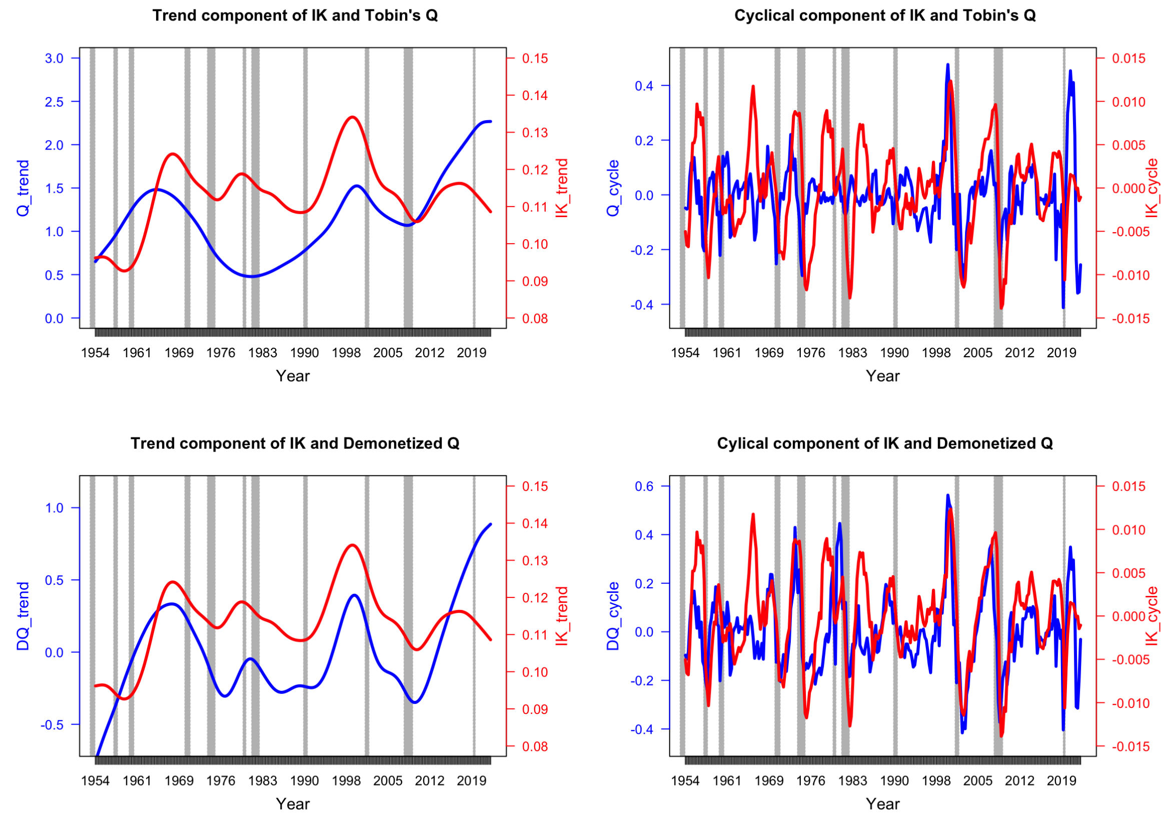
Note: Demonetized Q is obtained as residuals from the projection of average Q onto the concurrent nominal fed funds rate. Average Q is calculated as the ratio of the market value of installed capital to the replacement cost of installed capital. The numerator, the market value of NRSEIP, is measured by NFCB market value estimate of nonfinancial assets (FL102010405Q), less nonfinancial assets that are not NRSEIP. NFCB market value estimate of nonfinancial assets (FL102010405Q) is the sum of corporate equities (FL103164103Q), foreign direct investment in U.S (FL103192105Q), total liabilities (FL104190005Q), less total financial assets (FL104090005Q). Nonfinancial assets other than NRSEIP includes current costs of inventories excluding IVA (FL105020015Q), current costs of residential equipment (FL105012265Q), market value of residential real estate (FL105035023Q), book value of vacant land (FL105010103Q).NFCB nonfinancial assets (FL102010005Q) includes real estate at market value (FL105035005Q), equipment, current cost basis (FL105015205Q), nonresidential intellectual property products, current cost basis (FL105013765Q), and inventories excluding IVA, current cost basis (FL105020015). We remove components under NFCB nonfinancial assets that are not NRSEIP from NFCB market value estimate of nonfinancial assets. The denominator, the replacement costs of installed capital, is measured by contemporaneous NFCB nonresidential fixed assets in NRSEIP measured on the basis of current costs (FL105013865Q).

Figure 5: Investment rate and demonetized Q of nonfinancial corporate business



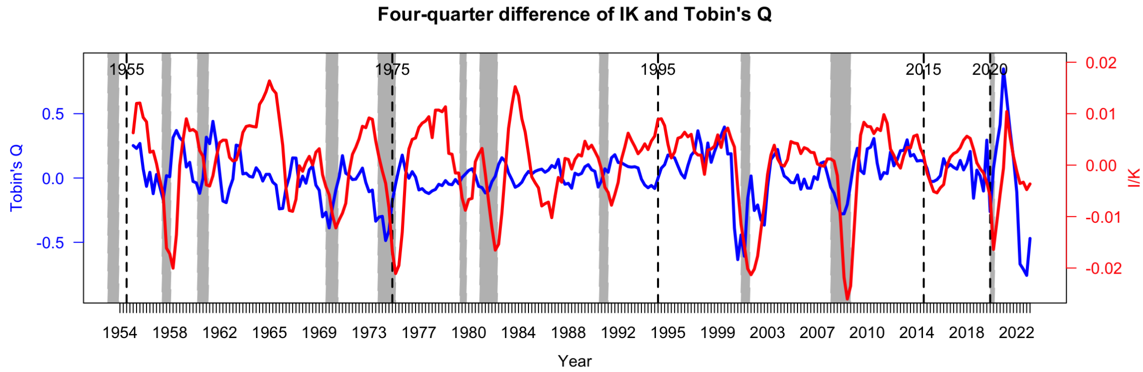
Note: The investment rate is calculated as the ratio of gross fixed investment to one-period lagged fixed assets. The numerator of investment rates, gross fixed investment, is measured by NFCB gross fixed investment in "nonresidential structures, equipment, and intellectual property products (NRSEIP) (FA105013005Q). The denominator is the one-period lagged NFCB nonresidential fixed assets in NRSEIP measured on the basis of current costs (FL105013865Q). Demonetized Q is obtained as residuals from the projection of average Q onto the concurrent nominal fed funds rate. Average Q is calculated as the ratio of the market value of installed capital to the replacement cost of installed capital. The numerator, the market value of NRSEIP, is measured by NFCB market value estimate of nonfinancial assets (FL102010405Q), less nonfinancial assets that are not NRSEIP. NFCB market value estimate of nonfinancial assets (FL102010405Q) is the sum of corporate equities (FL103164103Q), foreign direct investment in U.S (FL103192105Q), total liabilities (FL104190005Q), less total financial assets (FL104090005Q). Nonfinancial assets other than NRSEIP includes current costs of inventories excluding IVA (FL105020015Q), current costs of residential equipment (FL105012265Q), market value of residential real estate (FL105035023Q), book value of vacant land (FL105010103Q).NFCB nonfinancial assets (FL102010005Q) includes real estate at market value (FL105035005Q), equipment, current cost basis (FL105015205Q), nonresidential intellectual property products, current cost basis (FL105013765Q), and inventories excluding IVA, current cost basis (FL105020015). We remove components under NFCB nonfinancial assets that are not NRSEIP from NFCB market value estimate of nonfinancial assets. The denominator, the replacement costs of installed capital, is measured by contemporaneous NFCB nonresidential fixed assets in NRSEIP measured on the basis of current costs (FL105013865Q).

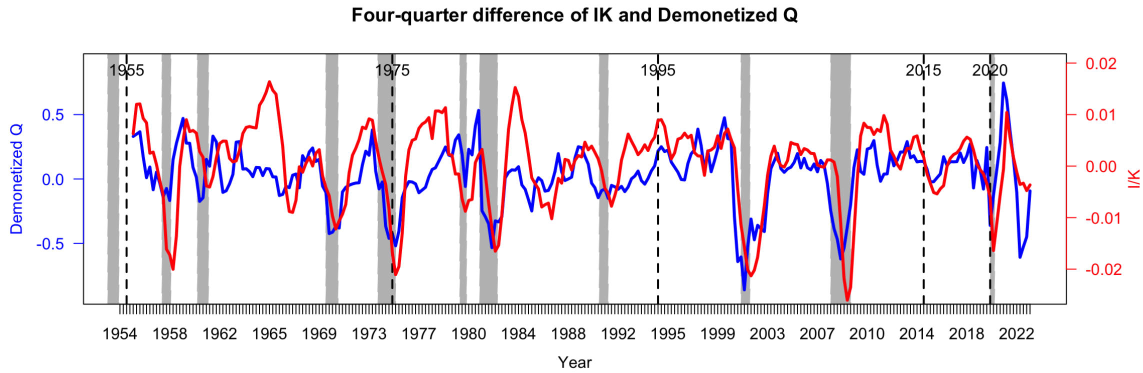
Figure 6: Investment rate, average Q, and demonetized Q of nonfinancial corporate business



Note: The investment rate is calculated as the ratio of gross fixed investment to one-period lagged fixed assets. The numerator of investment rates, gross fixed investment, is measured by NFCB gross fixed investment in "nonresidential structures, equipment, and intellectual property products (NRSEIP) (FA105013005Q). The denominator is the one-period lagged NFCB nonresidential fixed assets in NRSEIP measured on the basis of current costs (FL105013865Q). Demonetized Q is obtained as residuals from the projection of average Q onto the concurrent nominal fed funds rate. Average Q is calculated as the ratio of the market value of installed capital to the replacement cost of installed capital. The numerator, the market value of NRSEIP, is measured by NFCB market value estimate of nonfinancial assets (FL102010405Q), less nonfinancial assets that are not NRSEIP. NFCB market value estimate of nonfinancial assets (FL102010405Q) is the sum of corporate equities (FL103164103Q), foreign direct investment in U.S (FL103192105Q), total liabilities (FL104190005Q), less total financial assets (FL104090005Q). Nonfinancial assets other than NRSEIP includes current costs of inventories excluding IVA (FL105020015Q), current costs of residential equipment (FL105012265Q), market value of residential real estate (FL105035023Q), book value of vacant land (FL105010103Q).NFCB nonfinancial assets (FL102010005Q) includes real estate at market value (FL105035005Q), equipment, current cost basis (FL105015205Q), nonresidential intellectual property products, current cost basis (FL105013765Q), and inventories excluding IVA, current cost basis (FL105020015). We remove components under NFCB nonfinancial assets that are not NRSEIP from NFCB market value estimate of nonfinancial assets. The denominator, the replacement costs of installed capital, is measured by contemporaneous NFCB nonresidential fixed assets in NRSEIP measured on the basis of current costs (FL105013865Q).

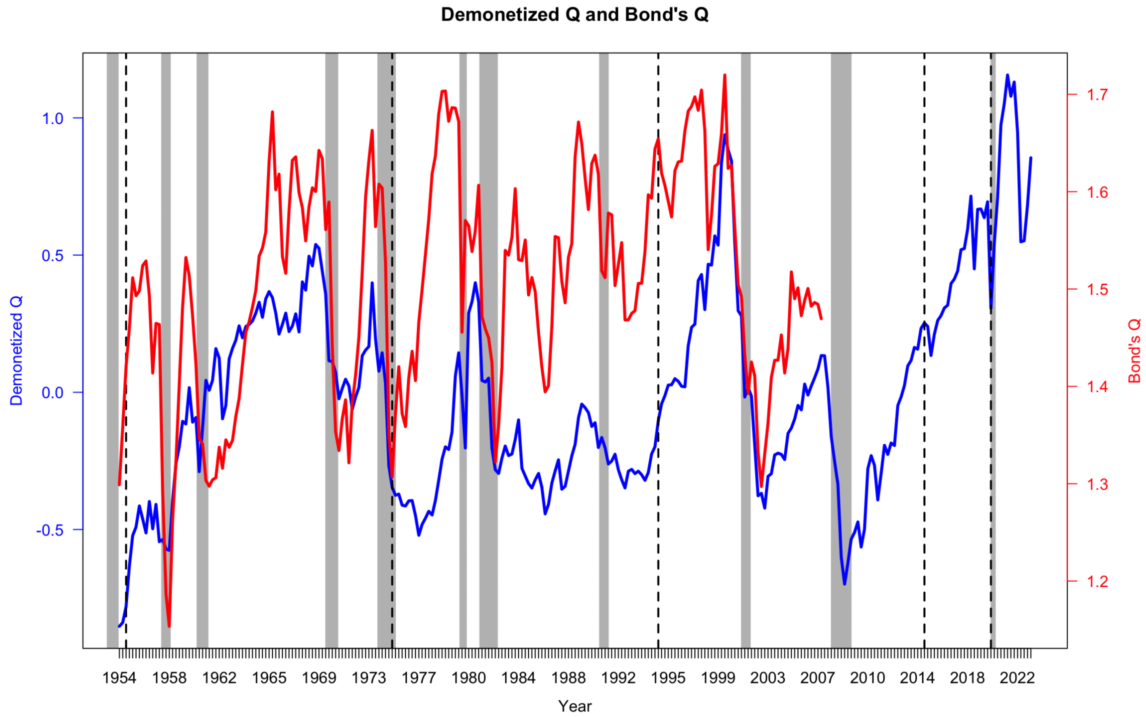
Figure 7: Four-quarter changes in investment rates, average Q, and demonetized Q of nonfinancial corporate business





Note: The investment rate is calculated as the ratio of gross fixed investment to one-period lagged fixed assets. The numerator of investment rates, gross fixed investment, is measured by NFCB gross fixed investment in "nonresidential structures, equipment, and intellectual property products (NRSEIP) (FA105013005Q). The denominator is the one-period lagged NFCB nonresidential fixed assets in NRSEIP measured on the basis of current costs (FL105013865Q). Demonetized Q is obtained as residuals from the projection of average Q onto the concurrent nominal fed funds rate. Average Q is calculated as the ratio of the market value of installed capital to the replacement cost of installed capital. The numerator, the market value of NRSEIP, is measured by NFCB market value estimate of nonfinancial assets (FL102010405Q), less nonfinancial assets that are not NRSEIP. NFCB market value estimate of nonfinancial assets (FL102010405Q) is the sum of corporate equities (FL103164103Q), foreign direct investment in U.S (FL103192105Q), total liabilities (FL104190005Q), less total financial assets (FL104090005Q). Nonfinancial assets other than NRSEIP includes current costs of inventories excluding IVA (FL105020015Q), current costs of residential equipment (FL105012265Q), market value of residential real estate (FL105035023Q), book value of vacant land (FL105010103Q).NFCB nonfinancial assets (FL102010005Q) includes real estate at market value (FL105035005Q), equipment, current cost basis (FL105015205Q), nonresidential intellectual property products, current cost basis (FL105013765Q), and inventories excluding IVA, current cost basis (FL105020015). We remove components under NFCB nonfinancial assets that are not NRSEIP from NFCB market value estimate of nonfinancial assets. The denominator, the replacement costs of installed capital, is measured by contemporaneous NFCB nonresidential fixed assets in NRSEIP measured on the basis of current costs (FL105013865Q).

Figure 8: Demonetized Q and Bond's Q



Note: Data on Bond's Q are obtained from Thomas Phillipon's website. Demonetized Q is obtained as residuals from the projection of average Q onto the concurrent nominal fed funds rate. Average Q is calculated as the ratio of the market value of installed capital to the replacement cost of installed capital. The numerator, the market value of NRSEIP, is measured by NFCB market value estimate of nonfinancial assets (FL102010405Q), less nonfinancial assets that are not NRSEIP. NFCB market value estimate of nonfinancial assets (FL102010405Q) is the sum of corporate equities (FL103164103Q), foreign direct investment in U.S (FL103192105Q), total liabilities (FL104190005Q), less total financial assets (FL104090005Q). Nonfinancial assets other than NRSEIP includes current costs of inventories excluding IVA (FL105020015Q), current costs of residential equipment (FL105012265Q), market value of residential real estate (FL105035023Q), book value of vacant land (FL105010103Q).NFCB nonfinancial assets (FL102010005Q) includes real estate at market value (FL105035005Q), equipment, current cost basis (FL105015205Q), nonresidential intellectual property products, current cost basis (FL105013765Q), and inventories excluding IVA, current cost basis (FL105020015). We remove components under NFCB nonfinancial assets that are not NRSEIP from NFCB market value estimate of nonfinancial assets. The denominator, the replacement costs of installed capital, is measured by contemporaneous NFCB nonresidential fixed assets in NRSEIP measured on the basis of current costs (FL105013865Q).

Table 1: Summary Statistics

	Mean	StdDev	AR(1)	Correlation Coefficient			
IK_t	0.113	0.011	0.969	1			
Q_t	1.157	0.481	0.984	0.217	1		
FFR_t	4.460	3.389	0.972	0.305	-0.632	1	
DQ_t	0.000	0.373	0.956	0.528	0.775	0	1

Note: This table reports summary statistics of investment rates, average Q, nominal fed funds rate, and demonetized Q. The investment rate IK_t is calculated as the ratio of gross fixed investment to one-period lagged fixed assets. The numerator of investment rates, gross fixed investment, is measured by NFCB gross fixed investment in "nonresidential structures, equipment, and intellectual property products (NRSEIP) (FA105013005Q). The denominator is the one-period lagged NFCB nonresidential fixed assets in NRSEIP measured on the basis of current costs (FL105013865Q). Demonetized Q, DQ_t, is obtained as residuals from the projection of average Q onto the concurrent nominal fed funds rate FFR_t. Average Q_t is calculated as the ratio of the market value of installed capital to the replacement cost of installed capital. The numerator, the market value of NRSEIP, is measured by NFCB market value estimate of nonfinancial assets (FL102010405Q), less nonfinancial assets that are not NRSEIP. NFCB market value estimate of nonfinancial assets (FL102010405Q) is the sum of corporate equities (FL103164103Q), foreign direct investment in U.S (FL103192105Q), total liabilities (FL104190005Q), less total financial assets (FL104090005Q). Nonfinancial assets other than NRSEIP includes current costs of inventories excluding IVA (FL105020015Q), current costs of residential equipment (FL105012265Q), market value of residential real estate (FL105035023Q), book value of vacant land (FL105010103Q).NFCB nonfinancial assets (FL102010005Q) includes real estate at market value (FL105035005Q), equipment, current cost basis (FL105015205Q), nonresidential intellectual property products, current cost basis (FL105013765Q), and inventories excluding IVA, current cost basis (FL105020015). We remove components under NFCB nonfinancial assets that are not NRSEIP from NFCB market value estimate of nonfinancial assets. The denominator, the replacement costs of installed capital, is measured by contemporaneous NFCB nonresidential fixed assets in NRSEIP measured on the basis of current costs (FL105013865Q).

Table 2: Benchmark regressions

	Dependent variable:				
		IK_{t+1}		Q_t	IK_{t+1}
	(1)	(2)	(3)	(4)	(5)
Q_t	0.005**		0.016***		0.011***
	t = 1.961		t = 5.033		t = 4.561
FFR_t		0.111***	0.253***	−8.778***	0.096*
		t = 3.709	t = 6.413	t = −6.541	t = 1.925
$Q_t * FFR_t$					0.199***
					t = 3.589
Observations	274	274	274	275	274
R^2	0.048	0.108	0.398	0.377	0.471
Note:					*p<0.1; **p<0.05; ***p<0.01

Note: The investment rate IK_t is calculated as the ratio of gross fixed investment to one-period lagged fixed assets. The numerator of investment rates, gross fixed investment, is measured by NFCB gross fixed investment in "nonresidential structures, equipment, and intellectual property products (NRSEIP) (FA105013005Q). The denominator is the one-period lagged NFCB nonresidential fixed assets in NRSEIP measured on the basis of current costs (FL105013865Q). Demonetized Q, DQ_t, is obtained as residuals from the projection of average Q onto the concurrent nominal fed funds rate FFR_t. Average Q_t is calculated as the ratio of the market value of installed capital to the replacement cost of installed capital. The numerator, the market value of NRSEIP, is measured by NFCB market value estimate of nonfinancial assets (FL102010405Q), less nonfinancial assets that are not NRSEIP. NFCB market value estimate of nonfinancial assets (FL102010405Q) is the sum of corporate equities (FL103164103Q), foreign direct investment in U.S (FL103192105Q), total liabilities (FL104190005Q), less total financial assets (FL104090005Q). Nonfinancial assets other than NRSEIP includes current costs of inventories excluding IVA (FL105020015Q), current costs of residential equipment (FL105012265Q), market value of residential real estate (FL105035023Q), book value of vacant land (FL105010103Q).NFCB nonfinancial assets (FL102010005Q) includes real estate at market value (FL105035005Q), equipment, current cost basis (FL105015205Q), nonresidential intellectual property products, current cost basis (FL105013765Q), and inventories excluding IVA, current cost basis (FL105020015). We remove components under NFCB nonfinancial assets that are not NRSEIP from NFCB market value estimate of nonfinancial assets. The denominator, the replacement costs of installed capital, is measured by contemporaneous NFCB nonresidential fixed assets in NRSEIP measured on the basis of current costs (FL105013865Q).

Table 3: Demonetized Q and aggregate investment

	Dependent variable:			
	IK_{t+1}			
	(1)	(2)	(3)	(4)
Q_t	0.005**			
	t = 1.961			
DQ_t		0.016***		0.016***
		t = 4.075		t = 5.033
FFR_t			0.111***	0.111***
			t = 3.709	t = 3.583
Observations	274	274	274	274
R^2	0.048	0.290	0.108	0.398
Note:	*p<0.1; **p<0.05; ***p<0.01			

Note: The investment rate IK_t is calculated as the ratio of gross fixed investment to one-period lagged fixed assets. The numerator of investment rates, gross fixed investment, is measured by NFCB gross fixed investment in "nonresidential structures, equipment, and intellectual property products (NRSEIP) (FA105013005Q). The denominator is the one-period lagged NFCB nonresidential fixed assets in NRSEIP measured on the basis of current costs (FL105013865Q). Demonetized Q, DQ_t, is obtained as residuals from the projection of average Q onto the concurrent nominal fed funds rate FFR_t. Average Q_t is calculated as the ratio of the market value of installed capital to the replacement cost of installed capital. The numerator, the market value of NRSEIP, is measured by NFCB market value estimate of nonfinancial assets (FL102010405Q), less nonfinancial assets that are not NRSEIP. NFCB market value estimate of nonfinancial assets (FL102010405Q) is the sum of corporate equities (FL103164103Q), foreign direct investment in U.S (FL103192105Q), total liabilities (FL104190005Q), less total financial assets (FL104090005Q). Nonfinancial assets other than NRSEIP includes current costs of inventories excluding IVA (FL105020015Q), current costs of residential equipment (FL105012265Q), market value of residential real estate (FL105035023Q), book value of vacant land (FL105010103Q).NFCB nonfinancial assets (FL102010005Q) includes real estate at market value (FL105035005Q), equipment, current cost basis (FL105015205Q), nonresidential intellectual property products, current cost basis (FL105013765Q), and inventories excluding IVA, current cost basis (FL105020015). We remove components under NFCB nonfinancial assets that are not NRSEIP from NFCB market value estimate of nonfinancial assets. The denominator, the replacement costs of installed capital, is measured by contemporaneous NFCB nonresidential fixed assets in NRSEIP measured on the basis of current costs (FL105013865Q).

Table 4: HP-filtered trend and cycle of investment, average Q, and demonetized Q

	Dependent variable:			
	$IK_{trend,t}$		$IK_{cycle,t}$	
	(1)	(2)	(3)	(4)
$Q_{trend,t-1}$	0.004**			
	t = 2.112			
$DQ_{trend,t-1}$		0.014***		
		t = 3.572		
$Q_{cycle,t-1}$			0.016***	
			t = 3.933	
$DQ_{cycle,t-1}$				0.021***
				t = 8.377
Observations	274	274	274	274
R^2	0.038	0.251	0.136	0.406
Note:				*p<0.1; **p<0.05; ***p<0.01

Note: The investment rate IK_t is calculated as the ratio of gross fixed investment to one-period lagged fixed assets. The numerator of investment rates, gross fixed investment, is measured by NFCB gross fixed investment in "nonresidential structures, equipment, and intellectual property products (NRSEIP) (FA105013005Q). The denominator is the one-period lagged NFCB nonresidential fixed assets in NRSEIP measured on the basis of current costs (FL105013865Q). Demonetized Q, DQ_t, is obtained as residuals from the projection of average Q onto the concurrent nominal fed funds rate FFR_t. Average Q_t is calculated as the ratio of the market value of installed capital to the replacement cost of installed capital. The numerator, the market value of NRSEIP, is measured by NFCB market value estimate of nonfinancial assets (FL102010405Q), less nonfinancial assets that are not NRSEIP. NFCB market value estimate of nonfinancial assets (FL102010405Q) is the sum of corporate equities (FL103164103Q), foreign direct investment in U.S (FL103192105Q), total liabilities (FL104190005Q), less total financial assets (FL104090005Q). Nonfinancial assets other than NRSEIP includes current costs of inventories excluding IVA (FL105020015Q), current costs of residential equipment (FL105012265Q), market value of residential real estate (FL105035023Q), book value of vacant land (FL105010103Q).NFCB nonfinancial assets (FL102010005Q) includes real estate at market value (FL105035005Q), equipment, current cost basis (FL105015205Q), nonresidential intellectual property products, current cost basis (FL105013765Q), and inventories excluding IVA, current cost basis (FL105020015). We remove components under NFCB nonfinancial assets that are not NRSEIP from NFCB market value estimate of nonfinancial assets. The denominator, the replacement costs of installed capital, is measured by contemporaneous NFCB nonresidential fixed assets in NRSEIP measured on the basis of current costs (FL105013865Q).

Table 5: Subsample regressions in level

	Panel A			
	IK_{t+1}			
	1954-1974	1975-1994	1995-2014	2015-2022
	(1)	(2)	(3)	(4)
Q_t	0.020^{**}	-0.016^{*}	0.031^{***}	-0.002
	t = 2.239	t = -1.815	t = 3.884	t = -1.193
Observations	81	79	79	32
R^2	0.164	0.134	0.413	0.016

	Panel B			
	IK_{t+1}			
	1954-1974	1975-1994	1995-2014	2015-2022
	(1)	(2)	(3)	(4)
DQ_t	0.030^{***}	0.012^{***}	0.033^{***}	-0.001
	t = 6.105	t = 2.713	t = 14.747	t = -0.495
Observations	81	79	79	32
R^2	0.539	0.112	0.865	0.004

Note: *p<0.1; **p<0.05; ***p<0.01

Note: The investment rate IK_t is calculated as the ratio of gross fixed investment to one-period lagged fixed assets. The numerator of investment rates, gross fixed investment, is measured by NFCB gross fixed investment in "nonresidential structures, equipment, and intellectual property products (NRSEIP) (FA105013005Q). The denominator is the one-period lagged NFCB nonresidential fixed assets in NRSEIP measured on the basis of current costs (FL105013865Q). Demonetized Q, DQ_t, is obtained as residuals from the projection of average Q onto the concurrent nominal fed funds rate FFR_t. Average Q_t is calculated as the ratio of the market value of installed capital to the replacement cost of installed capital. The numerator, the market value of NRSEIP, is measured by NFCB market value estimate of nonfinancial assets (FL102010405Q), less nonfinancial assets that are not NRSEIP. NFCB market value estimate of nonfinancial assets (FL102010405Q) is the sum of corporate equities (FL103164103Q), foreign direct investment in U.S (FL103192105Q), total liabilities (FL104190005Q), less total financial assets (FL104090005Q). Nonfinancial assets other than NRSEIP includes current costs of inventories excluding IVA (FL105020015Q), current costs of residential equipment (FL105012265Q), market value of residential real estate (FL105035023Q), book value of vacant land (FL105010103Q).NFCB nonfinancial assets (FL102010005Q) includes real estate at market value (FL105035005Q), equipment, current cost basis (FL105015205Q), nonresidential intellectual property products, current cost basis (FL105013765Q), and inventories excluding IVA, current cost basis (FL105020015). We remove components under NFCB nonfinancial assets that are not NRSEIP from NFCB market value estimate of nonfinancial assets. The denominator, the replacement costs of installed capital, is measured by contemporaneous NFCB nonresidential fixed assets in NRSEIP measured on the basis of current costs (FL105013865Q).

Table 6: Regressions in quarterly changes

Panel A. 1-quarter change

	Dependent variable:			
	$IK_t - IK_{t-1}$			
	(1)	(2)	(3)	(4)
$Q_{t-1} - Q_{t-2}$	0.008***			
	t = 3.874			
$DQ_{t-1} - DQ_{t-2}$		0.010***		0.009***
		t = 4.848		t = 4.479
$FFR_{t-1} - FFR_{t-2}$			0.092***	0.025
			t = 3.090	t = 0.813
Observations	273	273	273	273
R^2	0.083	0.181	0.077	0.185

Panel B. 4-quarter change

	Dependent variable:			
	$IK_t - IK_{t-4}$			
	(1)	(2)	(3)	(4)
$Q_{t-1} - Q_{t-5}$	0.014***			
	t = 4.264			
$DQ_{t-1} - DQ_{t-5}$		0.021***		0.017***
		t = 8.624		t = 7.805
$FFR_{t-1} - FFR_{t-5}$			0.220***	0.092***
			t = 5.308	t = 2.637
Observations	270	270	270	270
R^2	0.129	0.422	0.267	0.453
Note:	*p<0.1; **p<0.05; ***p<0.01			

Note: The investment rate IK_t is calculated as the ratio of gross fixed investment to one-period lagged fixed assets. The numerator of investment rates, gross fixed investment, is measured by NFCB gross fixed investment in "nonresidential structures, equipment, and intellectual property products (NRSEIP) (FA105013005Q). The denominator is the one-period lagged NFCB nonresidential fixed assets in NRSEIP measured on the basis of current costs (FL105013865Q). Demonetized Q, DQ_t, is obtained as residuals from the projection of average Q onto the concurrent nominal fed funds rate FFR_t. Average Q_t is calculated as the ratio of the market value of installed capital to the replacement cost of installed capital. The numerator, the market value of NRSEIP, is measured by NFCB market value estimate of nonfinancial assets (FL102010405Q), less nonfinancial assets that are not NRSEIP. NFCB market value estimate of nonfinancial assets (FL102010405Q) is the sum of corporate equities (FL103164103Q), foreign direct investment in U.S (FL103192105Q), total liabilities (FL104190005Q), less total financial assets (FL104090005Q). Nonfinancial assets other than NRSEIP includes current costs of inventories excluding IVA (FL105020015Q), current costs of residential equipment (FL105012265Q), market value of residential real estate (FL105035023Q), book value of vacant land (FL105010103Q).NFCB nonfinancial assets (FL102010005Q) includes real estate at market value (FL105035005Q), equipment, current cost basis (FL105015205Q), nonresidential intellectual property products, current cost basis (FL105013765Q), and inventories excluding IVA, current cost basis (FL105020015). We remove components under NFCB nonfinancial assets that are not NRSEIP from NFCB market value estimate of nonfinancial assets. The denominator, the replacement costs of installed capital, is measured by contemporaneous NFCB nonresidential fixed assets in NRSEIP measured on the basis of current costs (FL105013865Q).

Table 7: Demonetized Q and Bond's Q

	Dependent variable:			
	IK_{t+1}			DQ_t
	(1)	(2)	(3)	(4)
DQ_t	0.025***		0.015***	
	t = 7.599		t = 5.164	
BQ_t		0.083***	0.064***	
		t = 9.754	t = 7.007	
BQ_t				1.248***
				t = 3.619
Observations	211	211	211	212
R^2	0.431	0.583	0.709	0.195
Note:		*p<0.1; **p<0.05; ***p<0.01		

Note: Data on Bond's Q are obtained from Thomas Phillipon's website. The investment rate IK_t is calculated as the ratio of gross fixed investment to one-period lagged fixed assets. The numerator of investment rates, gross fixed investment, is measured by NFCB gross fixed investment in "nonresidential structures, equipment, and intellectual property products (NRSEIP) (FA105013005Q). The denominator is the one-period lagged NFCB nonresidential fixed assets in NRSEIP measured on the basis of current costs (FL105013865Q). Demonetized Q, DQ_t, is obtained as residuals from the projection of average Q onto the concurrent nominal fed funds rate FFR_t. Average Q_t is calculated as the ratio of the market value of installed capital to the replacement cost of installed capital. The numerator, the market value of NRSEIP, is measured by NFCB market value estimate of nonfinancial assets (FL102010405Q), less nonfinancial assets that are not NRSEIP. NFCB market value estimate of nonfinancial assets (FL102010405Q) is the sum of corporate equities (FL103164103Q), foreign direct investment in U.S (FL103192105Q), total liabilities (FL104190005Q), less total financial assets (FL104090005Q). Nonfinancial assets other than NRSEIP includes current costs of inventories excluding IVA (FL105020015Q), current costs of residential equipment (FL105012265Q), market value of residential real estate (FL105035023Q), book value of vacant land (FL105010103Q).NFCB nonfinancial assets (FL102010005Q) includes real estate at market value (FL105035005Q), equipment, current cost basis (FL105015205Q), nonresidential intellectual property products, current cost basis (FL1050137765Q), and inventories excluding IVA, current cost basis (FL105020015). We remove components under NFCB nonfinancial assets that are not NRSEIP from NFCB market value estimate of nonfinancial assets. The denominator, the replacement costs of installed capital, is measured by contemporaneous NFCB nonresidential fixed assets in NRSEIP measured on the basis of current costs (FL105013865Q).

Table 8: Return predictability by average Q and demonetized Q

	Dependent variable: Log excess returns (horizon in quarters)				
	$r^e_{t,t+1}$	$r^e_{t,t+4}$	$r^e_{t,t+12}$	$r^e_{t,t+20}$	$r^e_{t,t+40}$
	(1)	(2)	(3)	(4)	(5)
Q_t	−0.013	−0.049	−0.097	−0.200**	−0.735***
	t = −1.160	t = −1.394	t = −1.359	t = −2.246	t = −6.843
Observations	273	270	262	254	234
R^2	0.005	0.018	0.028	0.068	0.408
DQ_t	−0.039***	−0.134***	−0.273***	−0.477***	−0.946***
	t = −2.718	t = −3.045	t = −3.062	t = −5.137	t = −10.170
Observations	273	270	262	254	234
R^2	0.030	0.087	0.145	0.262	0.560
DQ_t	−0.039***	−0.132***	−0.259***	−0.456***	−1.036***
	t = −2.948	t = −3.257	t = −2.952	t = −4.992	t = −10.884
FFR_t	−0.262*	−0.727	−1.110*	−1.027	2.697**
	t = −1.726	t = −1.536	t = −1.838	t = −0.923	t = 2.422
Observations	273	270	262	254	234
R^2	0.041	0.108	0.168	0.275	0.602

Note: *p<0.1; **p<0.05; ***p<0.01

Note:The investment rate IK_t is calculated as the ratio of gross fixed investment to one-period lagged fixed assets. The numerator of investment rates, gross fixed investment, is measured by NFCB gross fixed investment in "nonresidential structures, equipment, and intellectual property products (NRSEIP) (FA105013005Q). The denominator is the one-period lagged NFCB nonresidential fixed assets in NRSEIP measured on the basis of current costs (FL105013865Q). Demonetized Q, DQ_t, is obtained as residuals from the projection of average Q onto the concurrent nominal fed funds rate FFR_t. Average Q_t is calculated as the ratio of the market value of installed capital to the replacement cost of installed capital. The numerator, the market value of NRSEIP, is measured by NFCB market value estimate of nonfinancial assets (FL102010405Q), less nonfinancial assets that are not NRSEIP. NFCB market value estimate of nonfinancial assets (FL102010405Q) is the sum of corporate equities (FL103164103Q), foreign direct investment in U.S (FL103192105Q), total liabilities (FL104190005Q), less total financial assets (FL104090005Q). Nonfinancial assets other than NRSEIP includes current costs of inventories excluding IVA (FL105020015Q), current costs of residential equipment (FL105012265Q), market value of residential real estate (FL105035023Q), book value of vacant land (FL105010103Q).NFCB nonfinancial assets (FL102010005Q) includes real estate at market value (FL105035005Q), equipment, current cost basis (FL105015205Q), nonresidential intellectual property products, current cost basis (FL105013765Q), and inventories excluding IVA, current cost basis (FL105020015). We remove components under NFCB nonfinancial assets that are not NRSEIP from NFCB market value estimate of nonfinancial assets. The denominator, the replacement costs of installed capital, is measured by contemporaneous NFCB nonresidential fixed assets in NRSEIP measured on the basis of current costs (FL105013865Q).