Ekonomik ve Sosyal Araştırmalar Dergisi, Cilt 17, Yıl 17, Sayı 1, 2021
The International Journal of Economic and Social Research, Vol. 17, Year 17, No. 1 2021

ADJUSTMENT COSTS AND THE TRADE-OFF BETWEEN q AND LAGGED INVESTMENT EFFECTS

UYARLAMA MALİYETLERİ VE q İLE GECİKMELİ YATIRIM ETKİLERİ ARASINDAKİ DENGELEME

Cihan ÇOBANOĞLU
Bolu Abant İzzet Baysal Üniversitesi, İİBF, İşletme Bölümü
(cihancobanoglu@ibu.edu.tr)
ORCID: *0000-0001-5698-318X*

ABSTRACT

A dynamic investment model is estimated by system generalized method of moments using a panel data of Turkish firms quoted over the period 2004–2017. The sample is split using firm size and rate of investment criteria to classify firms according to how likely they face financing constraints and high adjustment costs. The q theory of investment is consistent with the data of large but low-investment firms in that q is the sufficient statistic for investment and the implied adjustment costs are of reasonable magnitude. The coefficient on q for these firms is 0.60 which is very large compared to previous studies possibly due to reducing measurement errors by using cash flow to instrument q. The sensitivity of investment to q reduces not only with financing constraints but also with high adjustment costs. There is a trade-off between q and lagged investment effects on investment. The more likely that a firm faces high adjustment costs, the more lagged investment becomes important for its current investment. However, the coefficient of lagged investment is not higher than 0.23 in any estimation suggesting that lagged investment is important only when the adjustment costs are very high.

Keywords: Adjustment Costs, Tobin's q, Lagged Investment

ÖZ

Dinamik bir yatırım modeli, 2004–2017 döneminde piyasada işlem gören Türk firmalarının panel verileri kullanılarak sistem genelleştirilmiş momentler yöntemi ile tahmin edilmektedir. Firmaları finansal kısıtlar ve yüksek uyarlama maliyetleriyle karşılaşma ihtimalinin derecesine göre sınıflandırmak için firma büyüklüğü ve yatırım oranı kriterleri kullanılarak örneklem bölünmüştür. Yatırımın q teorisi, q'nun yatırım için yeterli istatistik olması ve tahmin edilen uyarlama maliyetlerinin makul büyüklükte olması açısından büyük ama düşük-yatırımlı firmalarının verileriyle tutarlıdır. Bu firmalar için q'nun katsayısı 0,60'tır ve muhtemelen nakit akışını q için araç değişkeni olarak kullanmanın ölçüm hatalarını azaltması nedeniyle bu katsayı önceki çalışmalara kıyasla çok büyüktür. Yatırımın q'ya duyarlılığı, sadece finansal kısıtlar ile değil aynı zamanda yüksek uyarlama maliyetleri ile de azalmaktadır. Yatırımda q ve gecikmeli yatırım etkileri arasında bir dengeleme vardır. Bir firmanın yüksek uyarlama maliyetleriyle karşılaşması ne kadar çok olası ise, gecikmeli yatırım mevcut yatırım için o kadar önemli hale gelmektedir. Ancak, gecikmeli yatırım katsayısının hiçbir tahminde 0,23'ten yüksek olmaması, gecikmeli yatırımın yalnızca uyarlama maliyetleri çok yüksek olduğunda önemli olduğunu göstermektedir.

Anahtar Sözcükler: Uyarlama Maliyetleri, Tobin'in q'su, Gecikmeli Yatırım

Gönderim Tarihi: *02.04.2021* Kabul Tarihi: *20.05.2021*

http://dergipark.gov.tr/esad ISSN:1306 - 2174

Introduction

Tobin (1969) suggested that if investment is to be related to anything it must be q. Any determinant of investment should affect investment only through q and shouldn't have an independent effect when current value of q is controlled. Therefore q should be a sufficient statistic for explaining investment. This statistic is defined as the ratio of two valuations of the same capital stock. The first one is the stock market value of capital and the second one is the replacement value of capital. The replacement value consists of both purchasing and installing costs of the capital stock. As long as the q ratio is higher than the equilibrium value of one, the market value of the capital is higher than its replacement cost and the firm should invest in that capital to increase its value. The theory is called the q theory of investment.

Some authors showed that the q theory of investment can be derived from the firm's optimization problem assuming there are convex costs in adjusting the capital stock. However, a problem about this theory is that the sufficient statistic for investment is the marginal q of new capital but what can be observed is the average q of the existing capital. Hayashi (1982) and Summers (1981) showed that under some circumstances marginal q and average q are related. This result led many studies to adopt Tobin's average q as a proxy for investment opportunities. However, empirical research on q is notorious for very low coefficients on q and excess sensitivity of other factors. The two properties are in contrast to the predictions of the theory. One of the factors that are generally found significant is lagged investment. This paper aims to assess the importance of lagged investment for firm's investment expenditures on different subsamples which are likely to face varying degrees of adjustment costs and examine if lagged investment effect can be reconciled with the q theory of investment.

The hypotheses of the study are based on the convex adjustment costs assumption of the q theory of investment. When marginal q is higher than one, a firm can try hard to invest to maximize its value. In extreme case, the rate of investment would be infinite if there weren't any adjustment costs or financial constraints. However, if the adjustment cost function is convex in investment, higher rates of investment incur adjustment costs higher than proportionality. As a result, higher rates of investment make a firm more reluctant to speed up its investment further. It leaves out some investment projects to later periods to reduce adjustment costs although marginal q is higher than one. The first consequence of high adjustment costs is lower coefficient on q in an investment equation and the second is a higher relation between current investment and lagged investment.

Lower coefficient on q is not only caused by high adjustment costs but it may also be a result of financing constraints. However, it is possible to identify financing constraints by looking at the sensitivity of investment to internal funds. If some firms are classified as financially unconstrained by using an a priori criterion and the classification is justified by the insensitivity of investment to internal funds, low coefficient on q can be interpreted as an evidence of high adjustment costs. As to lagged investment, it should be more important in firms with higher rates of investment because they are more likely to face high adjustment costs. Empirical findings of the study are in line with the predictions of the q investment theory and financing constraints hypothesis. The pattern in regression estimates shows that lagged investment effect can be explained by convex adjustment costs of capital stock.

A data of 192 non-financial Turkish firms which covers the period 2004–2017 is used for the empirical analysis. The sample is split by using firm size and rate of investment criteria to examine the cross-sectional differences in adjustment costs and financing constraints. Because of the dynamic nature of the investment model which includes lagged investment as an explanatory variable, system generalized method of moments is used for the estimations. Section 1 briefly outlines some issues about the q theory of investment such as high implied adjustment costs and excess sensitivity of investment to cash flow or lagged investment. Possible reasons of lagged investment effect are explained and a review of the scarce empirical literature on lagged investment is provided. Section 2 begins by presenting an empirical model of the q investment theory augmented with cash stock and lagged investment. It continues with a discussion of the hypotheses, estimation method, definition and description of the data. It also contains the dynamic panel regression estimates for the subsamples defined by size and investment criteria. The last section is a brief conclusion about the findings.

1. The Lagged Investment Effect

1.1. Insufficiency of q

Convex adjustment costs of capital are at the center of the q theory of investment. The common form of the adjustment costs used in deriving the q investment equation is quadratic. Summers (1981) and Blundell et al. (1992) among many others provide a derivation of the q investment equation with constant or error terms. If the adjustment costs function is defined as $A_{it}=(2\beta)^{(-1)}\ [(I/K)_{it} - \mu_i - \varepsilon_{it}]^2\ K_{it}$ then the investment equation is derived as $(I/K)_{it}= \beta q_{it} + \mu_i + \varepsilon_{it}$ where I/K is the ratio of investment to existing capital stock, q is marginal q, *i* and *t* are the indexes for firms and periods. The term μ_i is the normal value of the rate of investment of *i*th firm and the term ε_{it} is an error term. The average adjustment cost is zero at the rate of investment equal to its normal value. As the rate of investment speeds up over its normal value, adjustment costs become increasingly higher reducing the contribution of new investments to firm value. Adjustment costs also depend on $(2\beta)^{(-1)}$ which is a reciprocal function of the coefficient on q in the investment equation. Smaller coefficients on q imply higher adjustment costs.

Empirical results of the q theory of investment have been usually unsatisfactory in terms of the size of estimated coefficients on q and the sufficiency of q for investment. For example, Summers (1981) estimated the coefficient on q as 0.031 in his benchmark model. When the normal value of rate of investment is zero, this coefficient implies that for an investment of 20 percent of the capital stock (I/K=0.20), adjustment costs reach up to 65 percent of capital stock. Such a high value for adjustment costs is not plausible. Summers (1981) also estimate a constant of 0.088 which can be interpreted as the normal value of the rate of investment. In this case adjustment costs reduce to 20 percent of the capital stock. However it is still hard to explain adjustment costs that are as large as the size of investment. Fazzari et al. (1988) estimated even smaller coefficients on q when they also include cash flow into the investment equation. Low coefficients on q are generally attributed to measurement errors in q and capital market imperfections.

If q is a sufficient statistic for investment behavior, investment shouldn't be sensitive to any other variable in a regression where q controls for investment opportunities. However, in contrast to the theory, cash flow is generally found to be significant in the empirical q models of investment. There is a consensus about the statistical significance of cash flow although there are two conflicting views about its interpretation. According to the first view, cash flow can signal the profitability of investment. Explanatory power shifts from q to cash flow when there are measurement errors in q. According to the second view, the perfect capital markets assumption of the q theory of investment is not satisfied for some firms. Investment should depend on cash flow when the cost of external finance is higher than the opportunity cost of internal cash flow. Fazzari et al. (1988) showed the importance of availability of internal funds for financially constrained firms by comparing the coefficients on cash flow across firm groups. The reduced-form investment equation which explain investment with q as a proxy of investment opportunities and cash flow as a proxy of availability of internal funds have been the standard investment model for many studies.

1.2. Causes of Lagged Investment Effect

Beside cash flow, lagged investment is another variable that has sometimes been found to have an independent effect on investment apart from its effect through q. The reason of including lagged investment into the investment equation in some studies is that the error term ε in the estimated q models follows an AR(1) process so that $\varepsilon_{it} = \rho\varepsilon_{it-1} + v_{it}$ where v is the white noise. This process has two implications. First, AR(1) implies that there is a correlation between the error in one period and the error in the previous period. The serial correlation in the errors violates one of the assumptions of ordinary least squares. Second, AR(1) casts some doubt on the sufficiency of q for investment behavior because a possible cause of the serial correlation is omission of a variable from the regression. An omitted variable becomes a part of the error term and any trend in the omitted variable makes the errors serially correlated.

A cure for serially correlated errors as applied by Zhu and Singh (2016) is the transformation of the regression equation by replacing $\rho\varepsilon_{it-1}$ in the error term of the investment equation with the expression $\rho\varepsilon_{it-1} = \rho(I/K)_{it-1} - \rho\beta q_{it-1} - \rho\mu_i$. This expression is derived by solving the investment equation for the error, lagging one period and multiplying the error with ρ. The transformation introduces lagged variables into the regression equation without requiring any change in the theory. The theory doesn't change because the q theory of investment admits the existence of adjustment costs and slow reaction of investment to the fluctuations in q. As a result, lags of q can play a role in current investment. Lagged investment also fits in the theory because it can be interpreted as Koyck lag. For example lagged investment in the equation $(I/K)_{it} = \beta_1 (I/K)_{it-1} + \beta_2 q_{it} + \mu_i + \varepsilon_{it}$ represents distributed lags of q. Lagged investment or distributed lags of q are some of the variables that may cause the error term of basic q model to have an autoregressive structure when they are omitted in the regression.

There are some reasons to expect lagged variables to be determinants of current investment. Because of the formation of expectations and adjustment costs, the response of investment to price shocks is in the form of distributed lags. The formation of expectations about the future profitability of capital could cause lagged price variables to have effects on investment but theoretically these effects are captured by q. However the effect of lagged q on investment may still exist because of adjustment costs. There are gestational lags in the investment because making orders for equipment, delivery of orders and building a factory takes time. Speeding up the process and increasing the rate of investment is costly. A value maximizing firm spreads its investments to several years instead of undertaking all of the investment opportunities in one year. Therefore capital expenditures of a firm in a year contain expenditures for both new investments started that year and unfinished investments from previous years. As a result, on the one hand capital expenditure becomes stable across years and on the other hand lags of q become related to current investment.

The effect of lagged variables exists even if there isn't any measurement error in q. Abel and Blanchard (1986) found that even the calculated marginal q measures leave a large fraction of investment unexplained and give serially correlated residuals. Controlling the effect of lagged q is not easy because lagged q tend to be highly correlated with current q. Including lagged q into the investment equation along with current q may cause multicollinearity reducing the size and the significance of the coefficient on current q. On the other hand, lagged investment already contains the information that lagged q and other lagged factors of investment have. Therefore lagged investment can be a better proxy than lags of q for the unfinished projects of the previous years. Note that adjustment costs have opposite effects on the coefficients of q and lagged investment. For example high adjustment costs limit the rate of investment and cause larger part of investment projects to extend to the following years. The limits on investment and the existence of unfinished projects can cause investment to be unresponsive to the changes in q but be correlated with lagged investment.

Aside from adjustment costs, another reason for lagged investment effect is soft rationing. If a firm applies soft rationing for its divisions, expenditures of each division will have an upper limit. Soft rationing is plausible because it directs the divisional managers to select the investment projects which are really profitable. The limit of a division tends to be equal to the previous year's limit. The divisional managers can demand increasing the budget but large increases are less likely to be approved. Therefore budget limits may cause current investment to be related to lagged investment. Soft rationing may act like gestational lags and reduce the sensitivity of investment to the current q and increase the sensitivity of lagged q or lagged investment in an investment equation.

1.3. Empirical Literature

The empirical literature on the lagged investment effect is not large. Most of the existing studies use lagged investment to model serial correlation in the errors. For example, Devereux and Schiantarelli (1990) state that there is no theoretical reason to assume that the error of q investment equation is a white noise. To allow this error to follow an AR(1) process, the authors include lagged dependent variable and lagged explanatory variables into the initial investment equation. Their goal is testing the financial constraints hypothesis in the United Kingdom using an unbalanced data of 720 firms for the period 1969–1986. They estimate first differenced investment equations with generalized method of moments estimator on many subsamples including sample splits by size.

Devereux and Schiantarelli (1990) find that from small firms to large firms, the coefficient on lagged investment reduces from 0.17 to 0.10 and the coefficient on lagged cash flow increases from 0.23 to 0.40. The coefficient and significance of q is very small. Current assets variable as a stock measure of liquidity is insignificant when it is added to the equations. They interpret the positive coefficient on lagged investment as being consistent with that the error term of the initial investment equation follows AR(1) process. However they estimate significant positive coefficients on lagged cash flow in contrast to expected negative coefficients that AR(1) process implies. Authors interpret the positive effect of lagged cash flow as the investors of a firm may use the data of past cash flows in evaluating its creditworthiness.

Blundell et al. (1992) analyzes the importance of Tobin's q by using data and methods which are similar to those of Devereux and Schiantarelli (1990). Specifically, they estimate first differenced forms of investment equations with generalized method of moments (GMM) using an unbalanced data of 532 firms in the United Kingdom over the period 1975–1986. They compare GMM estimates with the estimates of other estimation methods which require stronger assumptions. The coefficient on lagged investment is 0.44 in OLS and 0.20 in FE. The former is biased upward because of firm-specific effects and the latter is biased downward because of dynamic panel bias. The coefficient is 0.32 in GLS and 0.25 in GMM. GLS estimator is consistent if q is strictly exogenous. GMM allows q to be endogenous however endogenous variables are instrumented by lagged variables which are valid only if the error of the levels equation is serially uncorrelated. The authors find evidence for their theory which allows this error to follow AR(1) and which may bias GMM estimates. As to the coefficient on q, it is small in all estimations for example around 0.008 in GMM.

Eberly et al. (2012) claim that lagged investment explains current investment better than q and cash flow combined. They use a balanced panel data of the largest 776 Compustat firms for the period 1981–2003 which enables abstracting from financial frictions. When they regress investment on lagged investment and natural logarithms of q and cash flow, they find that the coefficient of lagged investment is 0.62 in pooled ordinary least squares, 0.45 in fixed effects and 0.42 in Arellano–Bond regressions. The coefficients on q and cash flow are small in all regressions and even cash flow has negative sign in Arellano–Bond regression. Explanatory power of lagged investment is higher than that of q and cash flow in OLS and FE estimations. They also develop an investment–adjustment cost model which predicts a role for lagged investment, q and cash flow. According to this model, lagged investment effect depends positively on the adjustment costs and negatively on the persistence of price shocks. Authors solve the model numerically and construct a panel of firms by simulating it. The simulated data and the actual data have similar patterns according to fixed effects regressions.

Fazzari and Peterson (1993) don't directly test lagged investment but they test a hypothesis which assumes that changing the level of investment costly. The main reason for this assumption is convex adjustment costs of capital. In order to refrain from rapidly increasing adjustment costs, firms try to maintain a stable level of investment despite the fluctuations in cash flow. Financially unconstrained firms can substitute cash flow with external finance but even financially constrained firms can smooth investment using working capital as a source of fund. Such investment smoothing behavior may reduce the sensitivity of investment to cash flow for financially constrained firms. Fazzari and Peterson (1993) show that controlling the changes in working capital in the investment regression increases the size of the coefficient of cash flow for financially constrained firms. They state that when they add lagged investment to the investment equation as a robustness test, the coefficient on lagged investment is significant and other coefficients are unchanged. They don't report the details of that estimation. This finding suggests that lagged investment have an effect on investment independent of q and financial factors.

Gatchev et al. (2010) develop a dynamic system-of-equations model to account for the dependence of financial decisions across both time and variables. They claim that firms often replace a large proportion of their capital annually. Some projects may not be completed in a year and pausing projects is costly. Therefore investment can exhibit persistence and have inertia in its adjustment. Ignoring this persistence by omitting lagged investment may bias the sensitivity of investment to cash flow in static investment equations. They use data of non-financial Compustat firms over the period 1950–2007 for their empirical analysis and adopt weighted least squares as the estimation method. The estimated coefficient of cash flow is 0.47 in an investment equation controlling for q, size and year effects. When lagged investment is added to the equation, its coefficient is estimated as 0.87 and the coefficient of cash flow reduces to 0.08. Gatchev et al. (2010) interpret the results as supporting the persistence hypothesis but they ignore the possibility that lagged investment can act like firm effects. They estimate q coefficient as insignificant 0.00 in their complete model.

Some of the studies summarized above provide indirect evidence that lagged investment is more important for firms or years with higher levels of investments but they don't discuss these subsample differences. For example larger firms in Devereux and Schiantarelli (1990) have lower average investment and lower coefficient on lagged investment. Eberly et al. (2012) focus on only large firms and those firms have lower average investment and lower coefficient on lagged investment in the first subsample period. Fazzari and Peterson (1993) estimate more negative coefficient on the change in working capital for financially constrained firms which have higher average investment as reported by Fazzari et al. (1988). The behavior of constrained firms can be interpreted as those firms try harder to smooth investment because of higher adjustment costs of higher rates of investment.

The literature review shows that there is no consensus whether lagged investment is an unimportant outcome of the serially correlated errors or an important determinant of investment. The importance of lagged investment can depend on the adjustment costs and the adjustment costs can depend on the average investment. Firms with higher rate of investment should be more likely to face higher adjustment costs. Although there is indirect evidence about this prediction in the literature, to the best of author's knowledge no study focus on the differences in adjustment costs likely to exist between firms or interpret the differences in the rate of investment means and the coefficients on lagged investment. The aim of this study is to test whether lagged investment is an important factor in current investment expenditures and whether its importance is higher for firms that are likely to face higher adjustment costs. The results are expected to show whether convex adjustment costs assumption can explain the lagged investment effect.

2. Model and Estimation

2.1. Dynamic Investment Model

One of the assumptions of the q theory of investment is perfect capital markets but this assumption is not valid for many firms in the real world. Cash flow is an important determinant of investment for financially constrained firms. Because of its importance, cash flow is generally included into the empirical q investment equations. However, cash flow can act like a proxy for investment opportunities besides controlling the availability of internal funds. As a result, measurement errors in q can shift explanatory power from q to cash flow. Instead of flow measures like cash flow, it is also possible to control availability of internal funds by using stock measures of internal liquidity. The study employs cash stock instead of cash flow in the investment model to avoid underestimation of the coefficient on q. Cash flow is used as an instrument for q to alleviate the measurement errors in q.

In order to test the importance of lagged investment, the investment equation to be estimated is defined as a q investment model augmented with cash stock and lagged investment. The equation can be expressed as:

$$(I/K)_{it} = \alpha + \beta_1 (I/K)_{it-1} + \beta_2 Q_{it} + \beta_3 (CASH/K)_{it} + e_{it} \quad (1)$$

where $e_{it} = \mu_i + \lambda_t + u_{it}$

I represents the gross investment in property, plant and equipment during the period. CASH, K and Q represents beginning-of-period values of cash stock, replacement value of capital stock Tobin's q respectively. Investment and cash stock are divided by capital stock. The error term e represents full disturbance which is the sum of firm-specific fixed effect μ, time-specific fixed effect λ and idiosyncratic shock u. The observation for *i*-th firm and *t*-th period for any variable is represented by subscripts i and t.

Firms that face financial constraints and firms that face high adjustment costs may not respond to changes in q. Therefore a lower coefficient on q can indicate either financial constraints or high adjustment costs. The coefficient of q should be interpreted together with the coefficient of other two variables which are cash stock and lagged investment. While financial constraints implies a higher coefficient on cash stock, high adjustment costs imply a higher coefficient on lagged investment. Therefore the importance of q and lagged investment for current investment should depend on characteristics of the firms in the sample. Firms which have higher average investment are likely to face higher adjustment costs. The first hypothesis to be tested in this study is that the coefficient of lagged investment is higher for firms with higher rates of investment. The second hypothesis is that the coefficient of q is lower for firms with higher rates of investment even if they are not financially constrained.

In contrast to the neoclassical theory of investment which analyzes the difference of the optimal capital stock between two equilibrium points in time, the q theory of investment explains the movement of capital stock towards the equilibrium. Therefore the q theory of investment is dynamic in nature but the reduced-form of the model explains investment with only q which makes it look like a static model. The basic q investment equation and its cash flow augmented version are usually estimated with static panel data methods like fixed effects. On the other hand, lagged investment is a dynamic variable in an investment equation where current investment depends on its own past realizations. Such a dynamic model can contain dynamic panel bias and should be estimated by dynamic panel data methods such as difference or system generalized method of moments. Another advantage of dynamic panel data methods is that it can take q and liquidity variables as predetermined which are instrumented by their lags instead of assuming them to be either endogenous or exogenous.

2.2. System GMM Specification

Since the model is dynamic because of the lagged dependent variable, the estimates of the static panel data methods are biased. For example the coefficient on lagged investment is biased upward in the pooled ordinary least squares because of omitted firm heterogeneity. The coefficient is biased downward in the fixed effects because of dynamic panel bias pointed out by Nickell (1981). Dynamic panel data methods like difference or system generalized method of moments (GMM) are developed to estimate dynamic models without looking for instruments outside the dataset. In difference or system GMM, lagged dependent variable or other non-exogenous variables are instrumented by their lags in an efficient way that increasing these lags doesn't cause omitting years from the beginning of the sample. Difference GMM transforms the model into the first differenced form before the estimation. System GMM provides more efficient estimates than difference GMM using a system of two equations which are the equation in first differences and the equation in levels. Lagged levels instrument differences and lagged differences instrument levels in these estimation methods. The study estimate the dynamic investment model with Blundell–Bond system GMM estimator using the algorithm explained by Roodman (2009). [1]

Difference and system GMM doesn't require the explanatory variables be strictly exogenous because the estimators can make use of sequentially exogenous instruments available within the data. It is an important feature for estimating investment equation because explanatory variables can be simultaneously determined with investment or there may be feedback effects from past investment to current and future values of explanatory variables. The negative effect of investment on q is stronger if new investment opportunities do not arise frequently and the negative effect of investment on cash stock is stronger if there are financial constraints. In order to avoid simultaneous determination, q and stock variables are usually taken as the beginning-of-period values in the empirical literature. The tradition of using beginning-of-period values is followed in this study. Besides, in order to avoid feedback effects, q and cash stock are assumed sequentially exogenous (i.e. predetermined) instead of strictly exogenous wherever number of observations is sufficient for the instruments.

Unobserved firm effects such as intellectual capital or financial constraints and unobserved time fixed effects such as business cycles can be correlated with q and cash stock. Although firm and time fixed effects are included in the model, system GMM estimation is performed without including firm effects to avoid Nickel bias. Firm effects are removed from the equation in first differences because they are time-invariant. However, they exist in the error of the equation in levels. Changes in the variables which are used as instruments for the equation in levels are valid instruments only if they are uncorrelated with the fixed effects. Since q, cash flow or cash stock are measured as some ratios, they are not expected to deviate too far from their means and to violate the assumption of system GMM.

When q has measurement errors, the first and second lags of q may become invalid instruments. The solution of Blundell et al. (1992) is to remove them from the instrument list. However, earlier lags of q may convey less information about current investment opportunities, especially when it has measurement errors. An alternative solution is to use lags of cash flow instead of lags of q to instrument q. This approach has some roots in the literature. First, marginal q which is theoretically the true determinant of investment represents the net present value of future cash flows that marginal capital stock provides. Past cash flow realizations may predict future cash flows better than past average q values which are measured with errors. Second, Devereux and Schiantarelli (1990) find significant positive coefficient on lagged cash flow instead of current cash flow which implies that the investors evaluate the creditworthiness of a firm by looking past cash flow realizations. Investors' evaluation may also reflect into q. Third, Gilchrist and Himmelberg (1995) estimate a Fundamental Q by VAR forecasting equations. They expect Fundamental Q to contain the information content in cash flow that average q fails to contain. Finally, Millar (2005) states that the investment decision of a firm is based on forecasted q instead of current q because new investment becomes productive after some period of planning and building. It is possible that firms can forecast q by using past cash flows. Thus, the study uses lags of cash flow to instrument q in the GMM estimations.

1 Thanks to David Roodman for providing xtabond2 software that is used in this work.

2.3. Data and Definition of Variables

An unbalanced panel data is used in the estimations covering observations of 192 non-financial firms quoted in Turkish stock markets for the period including years between 2004 and 2017. On the one hand, investment is defined as a change in some balance sheet items and it is divided by the beginning-of-period capital stock. On the other hand, model contains lagged investment. Hence, the first two years of balance sheet data are lost for the calculation of variables leaving the period of 2006–2017 for the regression analyses. This period is the basis of the full sample of the study although using at least one lag of lagged investment as an instrument causes losing one more year in GMM. The calculation of replacement value of capital stock uses the oldest data available up to 1988.

Financial statement and stock market data required by the estimation of the model are obtained from Datastream and inflation data required for the calculation of real or replacement values is obtained from TURKSTAT. Firms with very low capital stock may not have a production function that satisfies the assumptions of q theory of investment. Besides very low capital stock in the denominator of a variable may cause some observations become outliers. Therefore observations are removed from the sample if current or lagged capital stock to total assets is lower than 0.15 where capital stock is measured with replacement value and balance sheet total assets are corrected for the replacement value of capital stock. Observations which have missing data in any of the variables of the model are dropped because they can't be used in the estimations. Observations which are not in a run of at least five consecutive non-missing observations are also dropped because they have very low number of lags available as instruments. The remaining 1879 observations constitute the full sample of the study. The number of observations in any firm is between 5 and 12 whereas the number of observations in any year is between 124 and 174.

Investment is defined as the change in property, plant and equipment adjusted for depreciation and revaluation. Replacement value of capital stock is calculated by setting initial value equal to book value and adjusting it for inflation, investment, and depreciation each year. Tobin's q is calculated as financial q where the total assets in the numerator is corrected for the market value of common equity and the total assets in the denominator is corrected for the replacement value of the capital stock. Cash stock is the sum of cash and cash equivalents. Cash flow is net income plus depreciation and amortization. Capital stock, cash stock and q are measured by beginning-of-period values. Each variable of the model except q are divided by the capital stock. Each variable is winsorized at its 1st percentile and 99th percentile before the regression analyses. Firm size as a criterion to select firms facing financing constraints is the real value of the beginning-of-period value of total assets in 2017 prices. Rate of investment as a criterion to select firms facing high adjustment costs is the ratio of investment to total assets where total assets corrected for the replacement value of capital stock. Rate of investment refers to the ratio of investment to capital stock when it is not used as a sample split criterion.

2.4. Summary Statistics

Firms are heterogeneous in the factors of investment and two important sources of heterogeneity are financing constraints and adjustment costs. In order to analyze their effects on the factors of investment, the full sample is split into two by using firm size and rate of investment criteria generating four subsamples. Sample split of each criterion is based on the comparison of the firm median and grand median of that criterion. As a result, firms are not allowed to change its class between two classes of firm size or between two classes of rate of investment. Observations of a firm are not dispersed into different subsamples. Since system GMM estimator uses some lags as instruments, the classification of firms is preferred to the classification of observations. Otherwise, either some observations of lagged instruments wouldn't be available or it would be hard to interpret when lagged instruments contain values of observations which are classified in other classes.

Table 1. Descriptive Statistics by Firm Classes

The full sample of observations is split into two subsamples using one of two criteria. The first one is firm size and is measured by real total assets. The second one is rate of investment and is measured by investment over total assets. The sample statistics of the sample splitting criteria and the regression variables are reported in the table. Two statistics of each variable for the related sample are the median and mean values reported one under another.

	Firm Size		**Rate of Investment**		**Full Sample**
	Small	**Large**	**Low-Inv.**	**High-Inv.**	
Real Total Assets (1,000 TL)	157,497 195,300	1,282,167 4,200,474	305,859 1,482,930	679,884 2,919,447	437,707 2,194,690
Investment / Total Assets	0.021 0.042	0.044 0.075	0.011 0.022	0.062 0.096	0.032 0.059
Investment / Capital Stock	0.048 0.146	0.111 0.168	0.026 0.092	0.139 0.223	0.080 0.157
Average q of Total Assets	1.071 1.416	1.146 1.411	1.062 1.324	1.160 1.505	1.114 1.414
Cash Flow / Capital Stock	0.095 0.146	0.231 0.285	0.125 0.178	0.208 0.253	0.167 0.215
Cash Stock / Capital Stock	0.063 0.204	0.148 0.291	0.095 0.237	0.106 0.257	0.102 0.247
Number of observations	941	938	948	931	1879
Number of firms	103	89	102	90	192

Summary statistics are shown in Table 1 for the four subsamples and the full sample. The statistics in each cell are the median and mean of the specified variable for the specified sample. Median values are lower than mean values in all cells indicating positive skewness in all variables. The two criteria are consistent with each other in terms of the patterns of median and mean values among the subsamples of each criterion. Small firms and low-investment firms have lower size, investment, q, cash flow and cash stock compared to large firms and high-investment firms. The differences in investment or q are more pronounced between two investment classes whereas the differences in cash flow or cash stock are more pronounced between two size classes. Investment in small firms or high-investment firms is highly skewed indicating investment jumps. The number of observations is not constant across subsamples because the classification is firm-based and firms have varying number of observations. Two subsamples from different criteria have common observations. The number of common observations is 602 between small firms and low-investment firms and 592 between large firms and high-investment firms which correspond to two thirds of the observations in any subsample.

Testing the hypotheses of the study requires using samples of firms with different rates of investment. Table 1 indicates that whether rate of investment is measured in proportion to total assets or capital stock, it is higher in large firms compared to small firms and it is higher in high-investment firms than low-investment firms. Moreover, the rate of investment of high-investment firms is even higher than that of large firms. In order to test if the differences are due to by chance, mean or median comparison tests could be performed. Mann-Whitney test is usually used to test for the differences in medians but it has a very strict assumption about the shapes of the distributions of populations. The t test is used to test for mean comparison but it assumes that the variable is approximately normally distributed. Besides, both of the tests are hard to implement for comparing groups of different criteria. It is not possible to define a group variable to be used by a Mann-Whitney or t test because large firms and high-investment firms have common observations.

Table 2. Bootstrap Estimates of Subsample Differences in Descriptive Statistics

Each subsample comparison has two lines of bootstrap estimates. The first one is about the median differences and the second one is about the mean differences for investment to capital stock.

	Difference	Std. Error	z	p-value
High-Inv. – Low-Inv.	0.113 0.131	0.007 0.022	16.16 6.02	0.000 0.000
Large – Small	0.063 0.022	0.009 0.022	7.17 0.99	0.000 0.323
High-Inv. – Large	0.028 0.055	0.006 0.017	4.41 3.26	0.000 0.001
Small – Low-Inv.	0.022 0.054	0.004 0.017	4.86 3.23	0.000 0.001

An alternative way to perform mean or median difference tests is bootstrapping. Bootstrapping mimics the random sampling process by reusing the existing data. After replicating sampling with replacement many times and calculating the statistic of interest each time, population value and standard error of the statistic can be estimated by the average and the standard deviation of the calculated statistics. Table 2 reports the bootstrap estimates for the difference in rate of investment medians or rate of investment means between two groups where rate of investment is measured by investment to capital stock. If there wouldn't be a difference between the subgroups, the differences would be near zero. Positive significant differences show that zero lies below the confidence intervals in all of the four comparisons in the table. The only exception to significant differences between two subsamples is the difference in means between large firms and small firms. The exception is probably due to investment jumps in small firms.

2.5. Regression Results for Sample Splits

Table 3 summarizes system GMM estimations of the model for four subsamples. Some diagnostics about the estimations are at the bottom of the table and they lead to the same decisions for all subsamples. The Wald χ^2 statistics are significant showing that the overall fit of the model in any sample is good. The number of instruments is lower than the number of firms in any subsample. Arellano–Bond tests (AB) reject AR(2) but don't reject AR(1) for first differenced error implying that idiosyncratic error in levels equation is not serially correlated for any subsample. Hansen tests don't reject the validity of instruments.

Table 3. Regression Results of Different Firm Classes

The table presents two-step system GMM estimates for four subsamples. Year dummies are included in all models and they are defined as IV-type instruments for levels equations. Dependent variable is investment over capital stock (I/K). Explanatory variables are lagged investment, financial q (Q) and cash stock over capital stock (CASH/K). Lagged investment and other explanatory variables are treated as predetermined variables. Q is instrumented by cash flow over capital stock (CF/K). All available lags of I/K, CF/K and CASH/K are used as GMM-type instruments in collapsed form for the first differences equation and all available lags of their first differences are used for the levels equation in the same way. The statistics in the square brackets are Windmeijer-corrected cluster-robust standard errors. *, **, *** denotes significance of a coefficient at 10%, 5%, and 1% significance levels respectively. Parentheses contain p-values for associated diagnostic tests.

Dep. Variable: $(I/K)_t$	**(i) Low-Inv.**	**(ii) Small**	**(iii) Large**	**(iv) High-Inv.**
$(I/K)_{t-1}$	-0.028 [0.04]	0.015 [0.04]	0.108** [0.05]	0.127** [0.05]
Q_t	-0.011 [0.03]	-0.029 [0.04]	0.106** [0.05]	0.096** [0.04]
$(CASH/K)_t$	0.172** [0.07]	0.230*** [0.09]	0.056 [0.04]	0.017 [0.03]
N	948	941	938	931
Wald χ^2 (14)	60.11 (0.00)	105.33 (0.00)	251.55 (0.00)	434.06 (0.00)
Instruments / Groups	79 / 102	79 / 103	79 / 89	79 / 90
AB for AR(1)	-4.19 (0.00)	-4.60 (0.00)	-3.98 (0.00)	-4.33 (0.00)
AB for AR(2)	-0.13 (0.89)	0.26 (0.80)	0.93 (0.35)	0.64 (0.52)
Hansen χ^2 (64)	72.02 (0.23)	68.32 (0.33)	70.22 (0.28)	69.98 (0.28)

The coefficient on q is around 0.10 in large firms and high-investment firms. The positive and significant q coefficients support q theory of investment. It is in contrast to most empirical studies which reports very low coefficients on q which implies very large adjustment costs even larger than investment itself. The implied adjustment costs for an average large firm can be computed by $A/K=(2\beta)^{-1}\ [(I/K)-N]^2$ where β is the coefficient on q and N is the normal rate of investment. If normal rate of investment is 0.17 which is the mean of investment in large firms, an investment of I/K=0.40 causes adjustment costs of $A/K = (2\times0.10)^{-1}\ [0.40-0.17]^2=0.26$. The size of implied adjustment costs is smaller than the size of investment. Therefore the coefficient on q is consistent with the q theory of investment. Besides, the coefficients on cash stock are insignificant in large firms and high-investment firms which support that q is a sufficient statistic for their investment.

In contrast to the results of large firms and high-investment firms, coefficients on q are not large or statistically different from zero in low-investment firms and small firms. The most possible causes of low q coefficients are financing constraints and high adjustment costs, assuming that other factors don't differ between different subsamples of firms. Since low-investment firms and small firms have lower rates of investment, they don't face high adjustment costs. The only remaining explanation for their low coefficient on q is that they are financially constrained. The coefficient on cash stock supports the financial constraints hypothesis. It is 0.17 for low-investment firms and 0.23 in small firms. Small firms have higher coefficient on cash stock because size is a more appropriate measure of financing constraints. Smaller firms are more likely to face costs due to asymmetric information on external finance. A higher cash stock at the beginning of the period means higher amount of low-cost internal funds available for financing investments. Lower cost of capital makes more investment projects acceptable.

Having established the fact that data are consistent with the theory, it is possible to interpret coefficients on lagged investment. The coefficient on lagged investment is insignificant and very small in low-investment firms and small firms. However, it is sligthly higher than 0.10 and statistically significant in large firms and high-investment firms. The results support the first hypothesis of the study. Large firms and high-investment firms have higher rates of investment and they are more likely to face high adjustment costs. In order to avoid higher adjustment costs, they don't speed up investment further so that some part of their investment is left to next years. As a result, some part of current investment spending is due to the investment projects that started previous years. Around 10% of investment from previous year is not economically significant however. This finding is in contrast to Eberly et al. (2012) who find that lagged investment plays an important role in current investment of large firms. They estimate coefficients for lagged investment larger than 0.40.

2.6. Regression Results for Unconstrained Firms

High-investment firms have higher rate of investment compared to large firms. As a result they are expected to have higher coefficient on lagged investment and lower coefficient on q. Table 3 shows that the coefficients on lagged investment for high-investment firms and large firms are 0.13 and 0.11 respectively. There is a little difference between two subsamples in terms of the coefficient on lagged investment and the coefficient on q is almost the same. Note that two thirds of the observations in these two subsamples are common. In order to examine the investment behavior of large firms and high-investment firms separately, the model is estimated for the intersection and difference subsets of these two subsamples. The subsets are assumed to consist of financially unconstrained firms as will be explained below.

Table 4 presents the descriptive statistics of rate of investment and the GMM estimations for three subsets of large firms and high-investment firms. Column (i) contains estimates of large firms which are not in the subsample of high-investment firms. Since they neither face financial constraints nor high adjustment costs, there is not an obstacle for them to adjust their investment to the changes in q. Column (ii) contains the estimates of firms which are classified in the subsamples of both large firms and high-investment firms. They are not financially constrained because of their size and they face high adjustment costs because of their high rate of investment. Their investment is expected to show some sensitivity to lagged investment but lower sensitivity to q compared to previous column because of adjustment costs. Column (iii) contains estimates of high-investment firms which are not in the subsample of large firms. Although they are small firms, they are not financially constrained because they are able to achieve high rates of investment. They are likely to be growing firms with high rates of investments and investment jumps.

Table 4. Results of The Subsets of Large or High-investment Firms

Panel A presents median and mean values of investment over capital stock reported one under another and Panel B presents two-step system GMM estimates for the intersection and difference subsets of large firms and high-investment firms. Explanations for the regressions are as in the previous table except for some differences. (1) Cash stock over capital stock is dropped from the explanatory variables and instrument list. (2) Cash flow over capital stock instruments Q but it is defined as IV-type instead of GMM-type. (3) Lags of lagged investment as GMM-type instruments are limited up to 5 lags.

Panel A: Median and Means of I/K

I / K	**(i) Large but not High-Inv.**	**(ii) Large and High-Inv.**	**(iii) Not Large but High-Inv.**
Median	0.054	0.152	0.130
Mean	0.099	0.208	0.250

Panel B: Regression results

Dep. Variable: $(I / K)_t$	**(i) Large but not High-Inv.**	**(ii) Large and High-Inv.**	**(iii) Not Large but High-Inv.**
$(I/K)_{t-1}$	0.097 [0.10]	0.099** [0.05]	0.232** [0.11]
Q_t	0.600*** [0.21]	0.251*** [0.07]	0.066 [0.20]
N	346	592	339
Wald χ^2 (13)	123.26 (0.00)	174.78 (0.00)	90.66 (0.00)
Instruments / Groups	23 / 35	23 / 54	23 / 36
AB for AR(1)	-2.91 (0.00)	-3.18 (0.00)	-3.23 (0.00)
AB for AR(2)	-0.76 (0.44)	0.67 (0.51)	0.72 (0.47)
Hansen χ^2 (9)	10.15 (0.34)	6.60 (0.68)	10.75 (0.29)

Panel A of the table shows that there is a sharp increase in the mean and median of the rate of the investment from Column (i) to Column (ii). It is an expected result because the statistics belong to two groups of large firms from two distinct investment subsamples. However, the change in the median and mean of investment from Column (ii) to Column (iii) is not so clear. Although Column (iii) has lower median, it has higher mean. The reason of the ambiguity stems from the fact that the statistics belong to two groups of high-investment firms which only differ by size. Lower median but higher mean for investment indicates investment jumps. Small firms in Colum (iii) invest with higher rates of investment when they invest. They can be expected to face higher adjustment costs compared to large firms in Column (ii) because of the jumps in some periods induced by their agility and ambition to be successful in competition.

Panel B of Table 4 summarizes system GMM estimations for three subsets of large firms and high-investment firms. The numbers of observations in any column is lower than the numbers of observations in the subsamples of large firms or high-investment firms. There are more observations in Column (ii) compared to other two columns because the subsamples of large firms and high-investment firms have more common observations than distinct observations. Since the subsets have lower number of observations, some changes are made in the model to reduce the number of instruments. First, cash stock is removed from the model because it is insignificant for both large firms and high-investment firms in Table 3. Second, cash flow which instruments q is assumed to be exogenous. Third, lag length of the lagged investment is limited to 5. Diagnostic tests at the bottom of Panel B don't indicate any problem about the validity of the instruments.

Three columns in Panel B of Table 4 are ordered in such a way that adjustment costs become more likely from left to right. This order causes some pattern in the coefficient on lagged investment and the coefficient on q. The coefficient on lagged investment is around 0.10 in the columns (i) and (ii). Its standard error is lower in the second column probably because the second column has higher number of observations. It reaches 0.23 in the column (iii) because of higher adjustment costs but it is still pretty lower than that of Eberly et al. (2012). Conversely, the coefficient on q is 0.60 in the column (i) which is quite high compared to the findings of previous studies. It gets lower from left to right as high adjustment costs become more probable until it turns out to be statistically insignificant in the column (iii). The q coefficient of 0.07 for small high-investment firms is the smallest in the table due to high adjustment costs but not financing constraints because financing constraints would reduce q coefficient further which would yield implausible adjustment costs. Since all three subset of firms are expected to be financially unconstrained, the findings about q support the second hypothesis of the study.

Conclusion

Regression estimates for different subsamples and subsets of the subsamples show that firms are heterogeneous in the factors of current investment. On the one hand, small firms which are more likely to face financial constraints have the highest sensitivity to internal liquidity. On the other hand, high-investment firms which are more likely to face high adjustment costs have the highest coefficient on lagged investment. Low-investment firms behave like small firms and large firms behave like high-investment firms because two thirds of the observations of the subsamples are common. Although size and investment criteria focus on different characteristics of firms, the results of two subsamples from different criteria come closer to each other because of the common observations.

It is difficult to select subsamples of firms which are financially unconstrained but face varying degrees of adjustment costs without reducing the size of subsamples. Since investment isn't sensitive to cash stock for the subsamples of large firms and high-investment firms, they can be regarded as financially unconstrained. The difference and intersection subsets of large firms and high-investment firms provides a way to compare financially unconstrained firms with varying degrees of adjustment costs. From low-investment large firms to high-investment large firms, and from high-investment large firms to high-investment small firms, high adjustment costs are more likely to be prevalent.

The coefficient of lagged investment increases from 0.10 to 0.23 and q reduces from 0.60 to 0.07 between the subsets of large firms and high-investment firms. There is a trade-off between q and lagged investment effects. The economic significance of the coefficients on lagged investment is not as high as previous findings such as findings of Eberly et al. (2012). However, the economic significance of the coefficients on q is quite high compared to findings of most empirical studies on investment. Both the size of the implied adjustment costs and the cross-sectional differences in the coefficients show that the q theory of investment is valid for financially unconstrained firms and lagged investment effect can be explained by convex adjustment costs. The success of the estimations that gives plausible coefficients on q can be attributed to using cash flow as an instrument for q. Future research is needed to confirm the results for different datasets.

Ethics Statement

No human studies are presented in this manuscript.

Author Contributions

The author confirms being the sole contributor of this work and has approved it for publication.

Conflict of Interest

The author declares that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

References

ABEL, A. B., & BLANCHARD, O. J. (1986). The Present Value of Profits and Cyclical Movements in Investment. Econometrica, 54(2), 249–273.

BLUNDELL, R., BOND, S., DEVEREUX, M., & SCHIANTARELLI, F. (1992). Investment and Tobin's Q: Evidence from Company Panel Data. Journal of Econometrics, 51, 233–257. https://doi.org/10.1016/0304-4076(92)90037-R

DEVEREUX, M., & SCHIANTARELLI, F. (1990). Investment, Financial Factors, and Cash Flow: Evidence from U.K. Panel Data. In R. G. HUBBARD (Ed.), Asymmetric Information, Corporate Finance, and Investment (p. 279–306). University of Chicago Press.

EBERLY, J., REBELO, S., & VINCENT, N. (2012). What explains the lagged-investment effect?. Journal of Monetary Economics, 59, 370–380. https://doi.org/10.1016/j.jmoneco.2012.05.002

FAZZARI, S. M., HUBBARD, R. G., & PETERSEN, B. C. (1988). Financing Constraints and Corporate Investment. Brookings Papers on Economic Activity, 1988(1), 141–206. https://doi.org/10.2307/2534426

FAZZARI, S. M., & PETERSEN, B. C. (1993). Working Capital and Fixed Investment: New Evidence on Financing Constraints. The RAND Journal of Economics, 24(3), 328–342. https://doi.org/10.2307/2555961

GATCHEV, V. A., PULVINO, T., & TARHAN, V. (2010). The Interdependent and Intertemporal Nature of Financial Decisions: An Application to Cash Flow Sensitivities. The Journal of Finance, 65(2), 725–763. https://doi.org/10.1111/j.1540-6261.2009.01549.x

GILCHRIST, S., & HIMMELBERG, C. P. (1995). Evidence on the Role of Cash Flow for Investment. Journal of Monetary Economics, 36, 541–572. https://doi.org/10.1016/0304-3932(95)01223-0

HAYASHI, F. (1982). Tobin's Marginal q and Average q: A Neoclassical Interpretation. Econometrica, 50(1), 213–224. https://doi.org/10.2307/1912538

MILLAR, J. N. (2005). Gestation Lags for Capital, Cash Flows, and Tobin's Q (Finance and Economics Discussion Series No. 24). Washington: Board of Governors of the Federal Reserve System (U.S.).

NICKELL, S. (1981). Biases in Dynamic Models with Fixed Effects. Econometrica, 49(6), 1417–1426.

ROODMAN, D. (2009). How to do xtabond2: An Introduction to Difference and System GMM in Stata. The Stata Journal, 9(1), 86–136.

SUMMERS, L. H. (1981). Taxation and Corporate Investment: A q-Theory Approach. Brookings Papers on Economic Activity, 1981(1), 67–140. https://doi.org/10.2307/2534397

TOBIN, J. (1969). A General Equilibrium Approach To Monetary Theory. Journal of Money, Credit and Banking, 1(1), 15–29. https://doi.org/10.2307/1991374

ZHU, Q., & SINGH, G. (2016). The Impacts Of Oil Price Volatility On Strategic Investment Of Oil Companies In North Amerıca, Asia, and Europe. Pesquisa Operacional, 36(1), 1–21. https://doi.org/10.1590/0101-7438.2016.036.01.0001