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Relative Energy Price and Firm-Level Investment in Europe

by

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ABSTRACT

A dynamic model of investment is estimated with data on non-financial firms in 15 European countries across 25 industries over 1991-2006. A rise in real energy price reduces the degree of persistence in the investment adjustment cost function. Panel results suggest that in manufacturing a 1% rise in real energy price reduces investment by a country's firms by 1.9% relative to that by firms in other countries with a smaller effect for non-manufacturing firms. The negative effect of a higher relative price of energy on firm-level investment is significantly less marked the larger the firm. Results imply that stabilizing the relative price of energy would steady firm investment with greater gains in stability at smaller and medium sized firms. Results are robust to consideration of country business cycle effect and firm leverage. Estimation of investment is based on the Euler equation approach with over 21,000 observations. Individual country regressions imply that a rise in the relative price of energy price has a statistically significant negative effect on firm-level investment in 14 out of 15 countries. To avoid dynamic panel bias estimation is by generalized method of moments with instrumental variables.

Key words: Dynamic Investment Model; Energy Price; European Firms

JEL Classification: E22, G31, O52, Q43

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1. Introduction

A large literature on the effects of oil price shocks on macroeconomic variables has appeared following work by Hamilton (1983) showing that increases in oil prices preceded recession in the U.S. economy. Most of this work has focused on aggregate real economic activity in the U.S. The significant effect of oil prices on aggregate activity has been confirmed by many authors including Lee *et al.* (1995), Hooker (1999), Hamilton (1996) and Gronwald (2008) for the U.S., and by Jimenez-Rodriguez and Sanchez (2005) for OECD countries and Cologni and Manera (2008) and Kilian (2008) for G-7 countries.

In contrast to work on the effect of energy or oil prices on economic aggregates comparatively little empirical work has appeared on effects of oil or energy prices on decisions at the firm or industry level. Studies considering the effects of oil price changes at industry level are by Jimenez-Rodriguez (2008) for France, Germany, Italy and Spain, Lee and Ni (2002) for the U.S., and Bohi (1989) for Germany, Japan, U.K. and U.S. In addition, for the U.S., Davis and Haltiwanger (2001) consider the effect of oil price change on job changes at plant level, Herrera (2007) considers the effect of oil price shocks on industry inventories, and Edelstein and Kilian (2007) examine the effect of energy price shocks on business fixed investment.

It is argued in this paper that a source for the influence of energy price shocks on real aggregate economic variables originates in effects at firm level. In this paper we investigate the effect of relative energy price on firm-level investment in manufacturing and in the non-financial sectors in 15 European countries. We will consider the effect of the variation in the relative price of energy between countries and over time on firm-level investment. The paper will contribute to the literature by examining a foundation for the effect of energy prices on aggregate economic activity at the level of the firm and by considering the consequences of

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energy price shocks with data for firms in 15 European countries. Changes in the relative price of energy have important public policy implications, including that of the effects on real activity, on stability of investment decisions by firms, and on possible disproportionate effects on smaller firms.

The use of data on a panel of firms across 15 countries rather than a panel of firms within a single country is very important. Examination of the effect of relative energy price on firm-level activity confronts the problem of finding variation in the energy price variable between firms and overtime given that data on firm investment is annual. In an analysis of firm-level investment behavior within a single country, the energy price would a time series with annual frequency to match that of the frequency of call report data on firms. Interpretation of results depends on the researcher being satisfied that what might be a small number of annual observations on energy price really yields the impact of energy price rather than other factors not named. By considering a panel of non-financial firms from 15 European countries we are able to consider the effect of change in the relative price of energy on firm investment not only over time, but between countries on firm level investment.

We estimate a dynamic model of investment based on the Euler equation approach with firm level data for 15 European countries across 25 industries on over 21,000 observations on total assets, capital expenditures, sales, cash stock and debt. Individual country regressions imply that a rise in the relative price of energy price has a statistically significant negative effect on firm-level investment in 14 out of 15 countries. To avoid dynamic panel bias, we use orthogonal deviation transformation due to Arellano and Bover (1995) and estimation is by generalized method of moments with instrumental variables. Panel regression results suggest that a 1% rise in real energy price reduces investment by a country's firms in that country by 1.2% relative to investment by firms in other countries.

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The effects are larger for manufacturing firms than for other non-financial firms. The results are robust to consideration of firm size, leverage, and country level business cycle.

The negative effect of a higher relative price of energy on firm-level investment is significantly less marked the larger the firm. Evidence of asymmetric effect of the relative price of energy on firm-level investment is weak. Relative energy price influences firm-level investment mainly by reducing the degree of persistence in investment in the investment adjustment cost function. The results imply that stabilizing the relative price of energy would help to steady firm-level investment with greater gains in stability at smaller and medium sized firms.

The investment model is outlined in the next section. Econometric issues are addressed in Section 3 and the data are discussed in Section 4. Empirical results are presented in Section 5 and Section 6 concludes.

2. Investment model

The dynamic model of investment presented below is based on the Euler equation approach introduced by Abel (1980). It has financial frictions modeled as in Gilchrist and Himmelberg (1998) and is similar to the models in Laeven (2003) and Love (2003). The investment model here modifies the setup in Love (2003). It is assumed that capital and energy are the only inputs in production, that it is costly to adjust capital, and that there is debt finance. We consider managers or shareholders, who choose investment and debt, to maximize the present value of dividends subject to capital accumulation and external financing constraints. The objective function (1) is given by:

$$V_t(K_t, B_t, P_t, \xi_t) = \max_{\{I_{t+s}, B_{t+s+1}\}_{s=0}^{\infty}} D_t + E_t\left[\sum_{s=1} \beta^s D_{t+s}\right] \quad (1)$$

subject to

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$$D_t = \Pi(K_t, P_t, \xi_t) - C(I_t, K_t, P_t) - I_t + B_{t+1} - (1+r_t)(1+\eta(B_t, K_t, \xi_t))B_t \qquad (2)$$

$$K_{t+1} = (1-\delta)K_t + I_t \qquad (3)$$

$$D_t \geq 0 \qquad (4)$$

where $E_t[.]$ is the expectations operator conditional on information available at time t, D_t is non-negative dividend payment to shareholders at time t, and β is the firm's discount factor. In equation (2), net predetermined profits is given by $\Pi(K_t, P_t, \xi_t)$, where K_t is capital stock at the start of time t, P_t is the real price of energy, and ξ_t is a productivity shock, $C(I_t, K_t, P_t)$ is the convex adjustment cost function for investment, I_t, B_t is the firm's debt at time t, r_t is the risk free rate of return, and $\eta(B_t, K_t, \xi_t)$ is an external finance premium. cost.[1] The capital accumulation constraint is given by equation (3), where δ is the rate of capital depreciation.

As in Gilchrist and Himmelberg (1998), financial friction is incorporated with additional cost of external finance, $\eta(B_t, K_t, \xi_t)$, being an increasing function of the level of borrowing. The gross required rate of return on debt is $(1+r_t)(1+\eta(B_t, K_t, \xi_t))B_t$. Let λ_t denote the Lagrangian with the constraint (4) that debt is non-negative. λ_t is the shadow cost of external funds due to information and agency cost.[2]

The Euler equation for investment with an imperfect capital market from the first order condition is:

$$1 + \frac{\partial C(I_t, K_t, P_t)}{\partial I_t} = E_t\left[\beta\left(\frac{1+\lambda_{t+1}}{1+\lambda_t}\right)\left\{\frac{\partial \Pi(K_{t+1}, P_t, \xi_{t+1})}{\partial K_{t+1}} + (1-\delta)\left(1 + \frac{\partial C(I_{t+1}, K_{t+1}, P_t)}{\partial I_{t+1}}\right)\right\}\right] \qquad (5)$$

[1]Note that in the setup here the cost of adjustment is not included in the profit function as in Laeven (2003). Here, cost of adjustment directly affects the dividends and as in the model in Love (2003) the profit function is a restricted profit function in the sense that it has already been maximized with respect to the adjustment cost. Investment is investment expenditure (as in Love, 2003) and not the quantity invested. Thus investment appears in the dividends function.

[2]We assume that investment will be productive in the next period with restricted profit function, that tax consideration can be ignored, and that the price of the investment good is normalized to unity.

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where $\partial C(I_t, K_t, P_t)/\partial I_t$ and $\partial \Pi(K_{t+1}, P_t, \xi_{t+1})/\partial K_{t+1}$ denote the marginal adjustment cost function of investment and the marginal benefit of investment, respectively. Equation (5) states that the marginal cost of investing at time t is equal to the discounted marginal cost of investing at time $t+1$. The stochastic discount factor, $\frac{1+\lambda_{t+1}}{1+\lambda_t}$, reflects the relative cost of external finance in periods $t+1$ and t.

Let the time varying stochastic discount factor for the relative cost of external finance in periods $t+s$ and t be defined as

$$\Phi_{t,t+s} = \frac{1+\lambda_{t+s}}{1+\lambda_t}. \tag{6}$$

Forward iteration on equation (5) yields:

$$1 + \frac{\partial C(I_t, K_t, P_t)}{\partial I_t} = E_t\left[\sum_{s=1} \beta^s (1-\delta)^s \left(\prod_{k=1}^{s} \left(\Phi_{t+k-1,t+k}\right)\right) MPK_{t+s}\right], \tag{7}$$

where MPK_{t+s} denotes $\partial \Pi(K_{t+s}, P_t, \xi_{t+s})/\partial K_{t+s}$. By Taylor series approximation equation (7) becomes:[3]

$$1 + \frac{\partial C(I_t, K_t, P_t)}{\partial I_t} = c + E_t\left[\sum_{s=1}^{\infty} \beta^s (1-\delta)^{s-1} MPK_{t+s}\right] + \gamma E_t\left[\sum_{s=1}^{\infty} \beta^s (1-\delta)^{s-1} \Phi_{t,t+s}\right] \tag{8}$$

An external finance premium is assumed to suggest a positive correlation between cash stock and investment. Following Love (2003), we assume that the stochastic discount factor for a firm is approximated by the stock of liquid assets relative to total assets. In equation (8), if the suffix i is introduced to indicate firm i, we assume that $\Phi_{it,t+s}$ is proportional to $cash_{it}$, the ratio of cash stock to total assets for firm i.

In equation (8) MPK_{it} is parameterized using a sales-based measure derived from the

[3] We follow Gilchrist and Himmelberg (1998) and Love (2003) and ignore $(\partial C/\partial K)_{t+1}$ since this effect is small relative to $(\partial \Pi/\partial K)_{t+1}$ in equation (5) and assume $E(\Phi_{t+s}) \cong 1$ and $E(MPK_{t+s}) \cong \gamma$ due to the range of the mean of the stochastic discount factor. Therefore, $\Phi_{t,t+s} MPK_{t+s} \cong \gamma_0 + \gamma \Phi_{t,t+s} + MPK_{t+s}$.

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profit maximization problem with a Cobb-Douglas production function. It is assumed that the marginal product of capital depends on the relative (or real) price of energy in country c, denoted P_{ct}.[4]

$$MPK_{it} = (\theta_{i0} - \theta_{i1} P_{ct}) \frac{S_{it}}{K_{it}}, \theta_{i1} > 0 \tag{9}$$

We assume a standard convex-adjustment cost function that includes includes lagged investment (to capital ratio) to capture strong persistence observed in the data. It is assumed that the real price of energy influences the degree of persistence in the adjustment cost function. This function is given by

$$C(I_{it}, K_{it}, P_{ct}) = \frac{\alpha}{2} \left(\frac{I_{it}}{K_{it}} - \rho(P_{ct}) \frac{I_{it-1}}{K_{it-1}} - v_i \right)^2 K_{it} \tag{10}$$

where α is the cost of capital, v_i is a firm-specific effect on the level of investment, and $\rho(P_{ct})$ is a measure of persistence that depends on the relative (or real) price of energy in country c. It is assumed that $\rho(P_{ct})$ is linear and that a rise in the relative price of energy reduces the degree of persistence in investment:

$$\rho(P_{ct}) = \rho_0 - \rho_1 P_{ct}, \rho_1 > 0 \tag{11}$$

If it is assumed that MPK_{it} and $Cash_{it}$ are vector autoregressive process of order one and that expectations are rational it can be shown, as in Laeven (2003), that equations (8), (9), (10) and (11) imply the empirical model:

$$\frac{I}{K}_{it} = (\beta_{10} + \beta_{11} P_{c,t}) \frac{I}{K}_{i,t-1} + (\beta_{20} + \beta_{21} P_{c,t}) \frac{S}{K}_{i,t} + \beta_3 Cash_{i,t} + f_i + d_{c,t} + u_{i,t} \tag{12}$$

where f_i is an unobserved firm-specific effect and $d_{c,t}$ denotes country-time dummies. u_{it} is an error term and orthogonal to any available information on time t. The empirical model in

[4]In the empirical framework, $MPK_{it} \approx const + \theta_i + \overline{\theta}(S / K_{it})$ and firm specific parameter θ_i is captured by fixed effect. θ_i is the ratio of capital share to markup.

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equation (12) corresponds to a linearization of the model's solution.

The sales capital ratio captures the effect of expected profit on investment in equation (12). Fazzari *et al.* (1988) argue that financially constrained firms' sensitivity of investment to cash flow is greater than that for unconstrained firms. The reason may not be primarily due to the presence of financial constraint, but as reasoned in Bond *et al.* (2004), may be due to expectations of future sales growth or profitability. Bloom *et al.* (2007) find cash flow terms are statistically significant and are needed for an empirical specification that is not rejected by the test of over-identifying restrictions.

In equations (12) a finding that the coefficient β_{11} is negative and statistically significant would imply that relative energy price affects capital expenditures mainly by delaying firm-level investment through affecting the persistence term in the adjustment cost function. A finding that the coefficient β_{21} is negative and statistically significant would imply that relative energy price affects capital expenditures working through firm-level growth prospects. The hypothesis in this paper are that

$$Ho: \beta_{11} < 0, \beta_{21} < 0 \tag{13}$$

3. Econometric Issues

3.1. GMM-IV Estimation

Several difficulties arise in estimating firm level investment with lagged dependent variable in equation (12). The main empirical concerns are the treatment of fixed effects and possible endogeneity problems as obstacles to obtaining consistent estimators. A standard within group estimator can eliminate the individual effect, but this creates a correlation between the transformed dependent variable and transformed error due to the lagged variables on the right-hand side. To avoid this dynamic panel bias, we use orthogonal deviation transformation (forward mean differencing) due Arellano and Bover (1995).

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Forward mean differencing has an advantage over mean differencing in estimating unbalanced panel data in terms of sample size. The specification of the investment capital ratio in equation (12) is estimated after forward-mean differences and country-time differences to remove an unobserved firm-specific effect, f_i and country-time dummies, $d_{c,t}$.[5]

The orthogonality condition for the model is given by $E[\varepsilon_t \mid Z_{t-s}] = 0$ for $s \geq 0$, where Z are our instrumental variables. The instrument variables are taken to be the first and second ($t-1$ and $t-2$) lags of all the variables in equation (12) and 2-digit industry dummies. The GMM-IV estimator with an optimal weight matrix can solve efficiency and possible simultaneity issues. We provide Hansen statistics to check the validity of specified instruments. Hansen statistics are equal to the value of the GMM objective function at the estimated parameter value, which under the null hypothesis of instruments orthogonal to the error term is asymptotically distributed with degrees of freedom equal to the difference in the number of instruments and regressors. That is $S \xrightarrow{d} \chi^2(J-K)$, where J is the number of instruments and K is the number of regressors. All regressions are estimated using asymptotically robust standard errors with firm clusters. To counter the difference in the number of observations per country, we apply a linear weighting regression.

3.2. GMM Bootstrap

Since the properties of the sample distribution for the weighting regression are unknown we apply the GMM bootstrap method proposed by Hall and Horowitz (1996).[6] The GMM bootstrap methodology will provide a check of the large sample properties of the Hansen test for the overidentification of instrumental variables in the dynamic panel data and

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[5]Forward-mean differencing or "Orthogonal deviation", proposed by Arellano and Bover (1995), removes only the mean of all future observations. This transformation is regarded as equivalent to first differences to eliminate fixed effects and GLS transformation to remove serial correlation. Bond and Meghir (1994), Gilchrist and Himmelberg (1998), and Love (2003) use this transformation to remove individual effect.

[6] Hall and Horowitz (1996) argue that asymptotic theory "often provides poor approximations to the distributions of test statistics from GMM estimator" (p. 891).

also provide the p-value of the Hansen test for the weighting regressions.

Hall and Horowitz (1996) draw a random sample in the traditional way and then recenter moment conditions with the bootstrap sample for the over-identification test to obtain bootstrap Hansen-test statistics,

$$\tilde{g}_N^b = \frac{1}{N}\sum_{i=1}^{N} g\left(z_i^b, \beta\right) - \frac{1}{N}\sum_{i=1}^{N} g\left(z_i, \hat{\beta}\right) \tag{14}$$

where $g\left(z_i^b, \hat{\beta}\right)$ is the GMM estimation from the sample, b denotes the bootstrap sample, β and $\hat{\beta}$ are the parameters we wish to estimate with the bootstrap sample and the original sample, and z_i^b and z_i are the instrumental variables from the bootstrap and the original sample. Substituting linear relationship produces a moment condition as follows:

$$\tilde{g}_N^b = Z^{b'}\left(y^b - x^b\beta\right) - Z'\hat{u}, \tag{15}$$

where $\hat{u} = y - x\hat{\beta}$ and $Z'\hat{u} = \frac{1}{N}\sum_{i=1}^{N} g\left(z_i, \hat{\beta}\right)$. The first order condition with respect to the parameter we estimate is,

$$J^b(\beta) = \tilde{g}_N^b(\beta)' W \tilde{g}_N^b(\beta). \tag{16}$$

Let $\tilde{\beta}$ minimize J^b. The bootstrap GMM estimator in the linear model is

$$\tilde{\beta} = \left[x^{b'} Z^b W Z^{b'} x^b\right]^{-1}\left[x^{b'} Z^b W\left[Z^{b'} y^b - Z'\hat{u}\right]\right], \tag{17}$$

where $\hat{u} = Y - Z\hat{\beta}$ is the in sample residual. We have a final bootstrap version of the Hansen J test:

$$J^b(\tilde{\beta}) = \tilde{g}_N^b(\tilde{\beta})'\left(\tilde{V}^b\right)^{-1}\tilde{g}_N^b(\tilde{\beta}), \tag{18}$$

where $\tilde{V}^b$ is an optimal weighting matrix with the bootstrap sample.

4. Data

Our sample contains data on energy prices and on non-financial firms in a group of 15 European countries for each of which there is relatively a larger number of observations.

We only include data for a country if there are at least 100 observations for that country. The group of 15 countries comprises Austria, Belgium, Denmark, Finland, France, Germany, Ireland, Italy, Netherland, Norway, Portugal, Spain, Sweden, Switzerland and United Kingdom.[7] OECD provides (consistent) data on CPI-energy for these European countries.

4.1. Firm-level data

Firm-level data are taken from the Compustat Global database from 1990 to 2006. These data are for publicly traded companies accounting for over 96% of European market capitalization. We have almost 21,000 observations on total assets, capital expenditures, sales, cash stock and debt.[8] All financial variables are converted to US dollar values by the appropriate exchange rates from the Compustat Global currency file. General rules with regard to the data are the following. We focus on non-financial firms. Firm-level data is eliminated if a firm has three or less years of coverage, if there are missing values for investment, capital stock, sales, cash stock, and cash flow, and if there are observations with negative values for assets, sales, or capital stock. In addition, we follow Gilchrist and Himmelberg (1998) in excluding observations with ratio of investment to capital stock above 2.5, ratio of sales to capital stock above 20, ratio of cash stock to total assets above 0.6, and outliers in the top and bottom 1% of the data. Details on construction and calculation of financial variables are summarized in the Appendix and in Table A-1.

Tables 1, 2, and 3 provide information on the number of observations and firms across European countries, across years and industries, and descriptive statistics for firms' key financial variables in each country. In Table 1 the number of observations and the distribution of firm size in terms of total assets varies widely across countries. In Table 3 there are

[7] For other OECD European countries there are relatively few firm-level observations. There are between 60 and 100 firm-level observations (the number in parenthesis) for Czech Republic (62), Hungary (67) and Turkey (61), and fewer than 30 for Greece (16), Poland (28), Slovakia (14), and Slovenia (12) and these countries are excluded.

[8] This paper uses cash stock as a measure of firms' internal funds instead of cash flow since use of cash flow to test sensitivity of investment is criticized by several recent papers, including Alti (2003) and Gomes(2001). Knyazeva *et al.* (2006) uses DATA 145 for I. We also obtain similar results with difference in capital stock.

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relatively fewer observations in the starting and ending periods. The total number of firms in the full sample is 1910, and the average number of firms is 127 for each country. We will estimate investment equations for each country separately and in a panel. In the panel regression we use a weighting regression approach to correct the over-representive in the sample of a large number of observations from bigger countries.

4.2. Energy Price Data by Country

To meet the requirement that data be consistent across countries, the real or relative price of energy will be taken to be the consumer price index for energy in ratio to the consumer price index exclusive of food and energy prices from OECD for each of fifteen European countries. Changes in such a broad measure of the relative price of energy will capture the comprehensive effect of relative energy price on firm investments. Data for the consumer price index for energy (CPI-E) in ratio to the consumer price index exclusive of food and energy prices for each of fifteen European countries appears in Table 4. These data are from OECD. With the exception of Italy, the relative price of energy is higher in 2006 than in 1992. The greatest increases in the relative price of energy over 1992-2006 are for consumers in the Netherlands, Norway and Sweden with average annual increases in relative prices of about 2.6%, 3.1% and 3.7%, respectively. A business cycle effect on investment will be identified by recession dummies for each European country as the deviation of GDP from trend.

5. Empirical Results

5.1. Single Country Investment Behavior

We start with basic single country regression of investment using GMM estimation. These results from estimating equation (12) are reported in Table 5. The lagged investment term shows a positive statistically significant coefficient in all single country regressions, except for Spain (which has a positive but not statistically significant coefficient). The

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estimated effect of lagged investment on current investment is given by $\beta_{10} + \beta_{11} P_{c,t}$, where the latter term captures the effect on persistence of the relative price of energy. In Table 5, estimates of β_{10} are greater than one because of the inclusion in the regression of the interaction term with relative price of energy. At the mean value for relative energy price, the estimate of persistence in investment for Austria, for example, is 0.343 (given by 1.709 – 1.424(0.959)).

The interaction of lagged investment with relative energy price (except for Spain) has a statistically significant negative coefficient. The median of the country point estimates for β_{11} is -1.152. This value implies an elasticity of the investment/capital ratio to relative price of energy of about 1.07. Thus, if the relative price of energy rises in country by 3% (energy prices are rising by 6% if inflation is 3%) investment will fall by about 3.2%.

The response of investment to marginal productivity of capital as measured by the sales to capital ratio is positive in 12 of the 15 country cases and statistically significant and positive for 9 countries. Cash stock has a positive coefficient in 6 out of 15 cases. The Hansen test statistics for over-identifying restrictions and the corresponding p -value indicates that single country regressions are satisfactory for all but one country (the exception is Great Britain). We now turn to panel estimation of equation (12) by GMM-IV.

5.2. Pooled country estimation

In equation (12) the slope coefficient β_{11}, for the effect on investment of the product of lagged investment and relative energy price ($(I/K)_{i,t-1} P_{c,t}$), and the slope coefficient β_{21}, for the effect on investment of the product of sales/capital ratio and relative energy price ($(S/K)_{i,t} P_{c,t}$), represent the joint effect of within-country and cross-country variation in

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relative energy price.[9] Results for pooled country data for non-financial firms are reported in models 1-3 in Table 6 and for firms in manufacturing in models 4-6 in Table 6. All regressions are weighted regressions, in which weights are equal to a value of one divided by the number of observations per country. In models 1 and 4 β_{21} is restricted to be zero, and in models 2 and 5 β_{11} is restricted to be zero.

In all regression models in Table 6 the coefficient on the interaction variable $(I/K)_{i,t-1}P_{c,t}$ is negative and always statistically significance at 1%, with the implication that a rise in the relative price of energy reduces persistence in investment. This is so in models 1 and 4 when β_{21} is restricted to be zero and in the unrestricted models 3 and 6. In contrast, the coefficient, β_{21}, on the interaction variable $(S/K)_{i,t}P_{c,t}$ is negative and statistically significance at 10% and 1% in models 2 and 5, respectively, when the coefficient on the interaction variable $(I/K)_{i,t-1}P_{c,t}$ is restricted to be zero, but is not statistically significant in the unrestricted models 3 and 6. For this reason we will favor the model specification given by models 1 and 4 in which change in the relative price of energy influences investment by reducing persistence in investment.

An implication of the results in model 1 in Table 6 is that if there is a 1.0% rise in relative price of energy in a country relative to that in other countries reduces investment by firms in that country by about 1.2% relative to investment by firms in other countries. Based on the regression in column (1) of Table 6 the elasticity of investment (in ratio to the capital stock) with respect to relative energy price is given by -1.243 $P_{c,t}((I_{t-1}/K_{i,t-2})/(I_t/K_{i,t-1}))$ ≈ -1.2. This effect is somewhat larger than that reported for the median result for the individual countries.

[9] It should be emphasized that extraction of the mean for each variable within country at each point in time and forward-mean differencing of each variable, eliminates from the intercept in equation (12) country, time, and firm fixed effects. The treated variables $(I/K)_{i,t-1}P_{c,t}$ and $(S/K)_{i,t}P_{c,t}$ continue to capture cross-country differences in relative energy prices.

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For firms in manufacturing the elasticity of investment with respect to the relative price of energy is somewhat greater than that for non-financial firms overall. The coefficient on the interaction variable $(I/K)_{i,t-1}P_{c,t}$ of -1.932 in model 2 implies that a 1.0% rise in the relative price of energy reduces investment by firms in manufacturing by about 1.9%.

5.3. Firm size effect

Firm size will now be introduced into the baseline model. Smaller firms may be more innovative in responding to energy price increases. Larger firms might have greater resources to substitute away from using higher priced energy. Sadorsky (2008) provides a survey on literature relating to firm size and oil price shocks and reports that stock prices of medium sized firms are disproportionately impacted by oil price changes.

Firm size is now introduced into the basic model as follows:

$$\frac{I}{K}_{it} = \beta_1 \frac{I}{K}_{i,t-1} + \beta_2 \frac{S}{K}_{i,t} + \beta_3 Cash_{i,t} + \beta_4 P_{c,t} \frac{I}{K}_{i,t-1} + \beta_5 Z_{i,t} \frac{I}{K}_{i,t-1} + \beta_6 P_{c,t} Z_{i,t} \frac{I}{K}_{i,t-1} + f_i + d_{c,t} + u_{i,t} \qquad (19)$$

where $Z_{i,t}$ is a firm size, as indicated by the log of real dollar total assets. In analysis below $Z_{i,t}$ will be defined differently to capture the influence of factors other than firm size.

In models 1, 2 and 3 in Table 7, equation (19) is estimated with $Z_{i,t}$ indicating firm size. The coefficient of the interaction of size and lagged investment, β_5, is negative (and statististically significant in two out of three cases) indicating that larger firms tend to have less persistence in investment than smaller firms. The coefficient on the interaction of lagged investment with relative energy price (β_4) is negative and statistically significant in models 2 and 3 in Table 7. Thus, the finding that increases in relative energy price are associated lower investment is robust to the addition of firm size to the basic regression equation. In model 3 in Table 7 the coefficient β_6 is positive and statistically significant, implying that the

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negative effect on investment of increases in the relative price of energy is less at larger firms. In the models in Table 7 the *P*-values for *J*-statistic test of over-identifying restrictions using Bootstrap simulation is consistent with a well chosen set of instrumental variables.

5.4. Business cycle effect

We now check for robustness of results by allowing outcomes to vary over the business cycle. Following Braun and Larrain (2005) we use the Hodrick-Prescott filter (Hodrick and Prescott (1980)) to identify country specific slowdowns in the economy. A dummy variable is defined to be equal to one if the real GDP is below the trend value (computed with the Hodrick-Prescott filter) for country c at time t, and equal to zero otherwise.

In columns 4, 5 and 6 of Table 7 results are reported for estimation of equation (19) where $Z_{i,t}$ is now a recession dummy variable (for recession dummy $Z_{i,t}$ will take the same value for firms in a particular country). In model (4), the coefficient of the interaction of $Z_{i,t}$ and lagged investment, β_5, is positive, but is not statistically significant. The effect of a rise in relative price of energy is robust to consideration of recession, in that the coefficient β_4 is negative and statistically significant in models 5 and 6 with the inclusion of additional variables to capture the effect of recession. In model (5) β_5 is positive and statistically significant, but may be reacting with relative price of energy. In model (6), which allows for an interaction term involving the relative price of energy and the recession variable, β_5 is negative and statistically significant, indicating less investment during recession. The coefficient of the interaction term involving the relative price of energy and the recession variable, β_6, is positive, implying that the negative impact of a rise in relative energy price on investment is less in recession than in recovery. The latter result may apply because investment is less in recession than during recovery.

5.5. Asymmetric energy price effect

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A well established result in the oil price literature is that oil price increases have a greater absolute impact on real activity than oil price decreases.[10] The negative effect of adjustment costs being partially offset when oil price fall and reinforced when oil prices rise is one among several explanations summarized by Jones et al. (2004) as an explanation for asymmetric effects. The possibility of an asymmetric effect of energy price rise on firm-level investment also arises if a rise in energy prices raises uncertainty and thus results in a delay in investment as argued by Pindyck (1991).

To capture the possibility of an asymmetric effect of energy prices of firm level investment the following equation will be estimated:

$$\frac{I}{K}_{it} = \beta_1 \frac{I}{K}_{i,t-1} + \beta_2 \frac{S}{K}_{i,t} + \beta_3 Cash_{i,t} + \beta_4 P_{c,t} \frac{I}{K}_{i,t-1} + \beta_5 W_{c,t} \frac{I}{K}_{i,t-1} + f_i + d_{c,t} + u_{i,t} \qquad (20)$$

where $W_{c,t} = 1$ if $P_{c,t} - P_{c,t-1} > 0$ and otherwise $W_{c,t} = 0$. There is an asymmetric effect of a rise in the relative price of energy within a country if β_5 is statistically significant. In line with the oil price effect literature the expectation is that if β_5 is statistically significant then $\beta_5 > 0$.

Results from estimating equation (20) appear in Table 8 for all non-financial firms in models 1 and 2 and for manufacturing firms in models 3 and 4. The effect of energy price dummy variable for a rise in real energy price is statistically significant and negative in models 1 and 3 when it appears alone in interaction with lagged investment. The relative price of energy in interaction with lagged investment appears in the regressions in models 2 and 4 and this variable retains statistical significance in the presence of the dummy variable. However, in model 2 for non-financial firms, β_5 while negative is only statistically significant at the 10% level, and in model 4 for manufacturing firms, β_5 is positive and

[10] An asymmetric impact on real activity of oil price changes has been noted by Mork (1989), Lee et al. (2001), Balke et al. (2002), Hamilton and Herrera (2004), Hooker (2002) and Huang et al. (2005).

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statistically insignificant. In results not reported, replacement of the dummy variable $W_{c,t}$ with a variable given by the absolute value of change in real energy price, $P_{c,t} - P_{c,t-1}$, does not yield a statistically significant result. We conclude that there is evidence of asymmetric effect of the relative price of energy on firm-level investment, but that the evidence is weak.[11]

5.6. Relative Price of Energy and Leverage

The effect of including the lagged leverage ratio, measured by total debt over total assets, as an additional explanatory variable in the regression equation (12) are reported in Table 9. In regression models in Table 9 (like those in Table 6) the coefficient on the interaction variable $(I/K)_{i,t-1}P_{c,t}$ is negative and always statistically significance at 1%, with the implication that a rise in the relative price of energy reduces persistence in investment. This result is unaffected by the presence of a leverage variable. The sign of the coefficient on leverage is negative as expected and is statistically significant in five models of six models in Table 9, including the preferred models 1 and 3 for non-financial and manufacturing firms, respectively. The introduction of leverage variable reinforces the conclusion of the earlier analysis that a rise in the relative price of energy influences investment by reducing persistence in investment.

In the models in Tables 7, 8 and 9 *P*-values for *J*-statistic test of over-identifying restrictions using Bootstrap simulation with 200 repetitions are consistent with a well chosen set of instrumental variables.

6. Conclusion

[11] This conclusion needs to be qualified by noting that given the frequency of the data the asymmetry analyzed in the literature on the macroeconomic effect of oil prices is not well captured by the dummy variable considered in this paper. For instance, the frequency of the data makes it impossible to compute whether an increase represented a higher price than the previous 12 or 36 month maximum or whether it was just a correction for declines in the price in the same period (as Hamilton's (1996, 2003) net oil price increase would do). The dummy also doesn't capture asymmetry as proposed by Mork (1989) or the type of nonlinearity implied in the scaled oil price increase of Lee, Ni and Ratti (1995). In general, the more recent literature on the asymmetric effect of oil price shocks deals with the asymmetry of the dynamic response, as in Kilian and Vigfusson (2009), and not just with the slope effect captured in this analysis.

In this paper we investigate the effect of relative energy price on firm-level investment in European countries. By considering a panel of non-financial firms from 15 European countries we are able to consider the effect of change in the relative price of energy on firm investment not only over time, but between countries on firm level investment. A dynamic model of investment based on the Euler equation approach is estimated with over 21,000 firm-level observations on total assets, capital expenditures, sales, cash stock and debt. Individual country regressions imply that a rise in the relative price of energy price has a statistically significant negative effect on firm-level investment in 14 out of 15 countries. To avoid dynamic panel bias data are transformed by orthogonal deviation transformation due Arellano and Bover (1995) and estimation is by generalized method of moments with instrumental variables.

The relative energy price influences firm-level investment by reducing the degree of persistence in investment in the investment adjustment cost function. Panel regression results suggest that a 1% rise in energy price relative to other prices in a country reduces investment by firms in that country by 1.2% relative to investment by firms in other countries. For manufacturing firms the effect a 1% rise in energy price is a reduction in investment of 1.9%. This result is robust to consideration of firm size, leverage, and country level business cycle. The negative effect of a higher relative price of energy on firm-level investment is significantly less marked the larger the firm. Evidence of asymmetric effect of the relative price of energy on firm-level investment is weak.

The results imply that stability in the relative price of energy would help stabilize firm-level investment and that much of this benefit would accrue at smaller and medium sized firms. Future work might focus on considering the impact of energy prices and their components on disaggregate activity including firm-level investment.

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Table 1: Firm-level data across countries: 1991-2006 (E 15 countries)

Country	Code	Number of Observations	Percent of Observations	Number of Firms	TA	IK	SK	Cash	CF	LEV
Austria	AUT	563	2.65	51	988	0.202	3.64	0.092	0.246	0.259
Belgium	BEL	520	2.45	43	1,348	0.252	4.689	0.101	0.382	0.280
Switzerland	CHE	1,233	5.80	125	2,749	0.166	3.564	0.132	0.304	0.261
Germany	DEU	3,544	16.67	279	3,986	0.243	5.161	0.084	0.307	0.210
Denmark	DNK	960	4.52	86	753	0.242	4.364	0.122	0.310	0.301
Spain	ESP	776	3.65	66	1,853	0.195	3.08	0.073	0.279	0.228
Finland	FIN	695	3.27	64	1,955	0.238	4.41	0.095	0.344	0.281
France	FRA	2,379	11.19	199	3,322	0.262	6.257	0.111	0.399	0.251
United Kingdom	GBR	6,457	30.37	693	2,081	0.205	4.526	0.093	0.286	0.206
Ireland	IRE	336	1.58	23	1,068	0.195	4.156	0.129	0.307	0.278
Italy	ITA	690	3.25	71	3,530	0.209	4.159	0.105	0.324	0.242
Netherlands	NLD	1,091	5.13	100	4,726	0.222	5.793	0.074	0.369	0.249
Norway	NOR	683	3.21	84	1,229	0.267	3.404	0.116	0.227	0.355
Portugal	PRT	172	0.81	14	1,718	0.238	2.65	0.061	0.225	0.278
Sweden	SWE	826	3.89	96	2,133	0.219	4.693	0.099	0.347	0.241
Total		20,925	100.00	1,910						
Mean		1395.0		127	2,229	0.224	4.303	0.099	0.310	0.261
Median					1,955	0.222	4.364	0.099	0.307	0.259
Std					1,190	0.028	0.971	0.021	0.053	0.037

Notes: Data from Compustat Global. Variables are discussed and defined in Table A-1: TA - total assets in million U.S dollar units; IK - ratio of investment to capital stock; SK - ratio of sales to capital stock; Cash - ratio of cash stock to total assets; CF - ratio of cash flow to capital stock; LEV – leverage is ratio of total debt to total assets. General rules with regard to the data are the following. We focus on non-financial firms (with SIC less than 6000). Firm-level data is eliminated if a firm has three or less years of coverage, if there are missing values for investment, capital stock, sales, cash stock, and cash flow, and if there are observations with negative values for assets, sales, or capital stock. In addition, we follow Gilchrist and Himmelberg (1998) and Love (2003) in excluding observations with IK > 2.5, SK > 20, cash > 0.6, and outliers in the top and bottom 1% of the variable values.

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Table 2: Descriptive Statistics across Industries

Industry	SIC	Industry name	IK	SK	Cash	CF	LEV	Number of Observations	Percent of Observations
1	0	Agriculture, forestry and fishing	0.162	2.402	0.133	0.245	0.195	144	0.69
2	1	Mining	0.241	1.637	0.111	0.211	0.253	527	2.52
3	2	Construction	0.241	6.564	0.126	0.285	0.188	889	4.26
4	4	Transportation, communication, electric, gas and sanitary services	0.194	2.275	0.097	0.233	0.288	2,586	12.39
5	5	Wholesale trade and retail trade	0.235	6.437	0.088	0.309	0.229	3,109	14.89
6	20	Food and kindred products	0.207	4.270	0.081	0.287	0.255	1,619	7.76
7	21	Tobacco manufactures	0.205	4.378	0.182	0.850	0.485	41	0.20
8	22	Textile mill products	0.201	4.575	0.066	0.202	0.255	495	2.37
9	23	Apparel and fabrics-based products	0.217	6.932	0.090	0.392	0.224	473	2.27
10	24	Lumber and wood products	0.221	4.554	0.078	0.253	0.280	231	1.11
11	25	Furniture and fixtures	0.215	4.724	0.095	0.300	0.223	303	1.45
12	26	Paper and allied products	0.182	2.617	0.070	0.220	0.265	628	3.01
13	27	Printing and publishing	0.246	5.374	0.108	0.536	0.215	625	2.99
14	28	Chemicals and allied products	0.220	3.955	0.115	0.355	0.209	1,419	6.80
15	29	Petroleum refining	0.173	4.758	0.046	0.253	0.219	127	0.61
16	30	Rubber and plastics products	0.223	3.945	0.072	0.311	0.257	430	2.06
17	31	Leather and leather products	0.242	8.707	0.140	0.346	0.149	81	0.39
18	32	Stone, clay, glass, and concrete	0.187	2.924	0.082	0.246	0.230	970	4.65
19	33	Primary metal industries	0.209	3.797	0.070	0.266	0.240	724	3.47
20	34	Fabricated metal products	0.233	5.050	0.085	0.321	0.247	725	3.47
21	35	Machinery, except electrical	0.222	6.010	0.111	0.357	0.219	1,747	8.37
22	36	Electrical and electronic machinery, equipment and supplies	0.267	5.663	0.115	0.360	0.222	1185	5.68
23	37	Transportation equipment	0.268	5.347	0.111	0.360	0.241	775	3.71
24	38	Instruments; Photographic, medical and optical goods; Clocks	0.265	5.514	0.131	0.491	0.212	726	3.48
25	39	Miscellaneous manufacturing industries	0.258	5.950	0.111	0.458	0.213	297	1.42

Notes: Data from Compustat Global. Variables are discussed and defined in Table A-1: TA - total assets in million U.S dollar units; IK - ratio of investment to capital stock; SK - ratio of sales to capital stock; Cash - ratio of cash stock to total assets; CF - ratio of cash flow to capital stock; LEV - leverage is ratio of total debt to total assets.

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Table 3: Descriptive statistics for firm-level data across years

Year	IK	SK	Cash	CF	LEV	No. of Obs.	% of Obs.
1991	0.254	4.445	0.100	0.308	0.227	843	4.03
1992	0.226	4.080	0.102	0.255	0.233	927	4.43
1993	0.192	3.935	0.110	0.257	0.229	962	4.60
1994	0.224	4.766	0.109	0.325	0.217	993	4.75
1995	0.241	4.920	0.102	0.316	0.226	1,099	5.25
1996	0.229	4.617	0.105	0.310	0.222	1,300	6.21
1997	0.220	4.468	0.107	0.321	0.219	1,754	8.38
1998	0.259	4.976	0.101	0.351	0.228	1,882	8.99
1999	0.222	4.415	0.094	0.314	0.236	1,926	9.20
2000	0.228	4.681	0.087	0.333	0.247	1,886	9.01
2001	0.224	4.561	0.085	0.276	0.258	1,834	8.76
2002	0.217	4.969	0.089	0.287	0.259	1,735	8.29
2003	0.202	5.208	0.096	0.317	0.251	1,651	7.89
2004	0.202	5.131	0.098	0.363	0.239	1,596	7.63
2005	0.173	4.425	0.093	0.316	0.253	401	1.92
2006	0.213	4.675	0.104	0.404	0.247	136	0.65
Total	0.223	4.692	0.097	0.314	0.237	20,925	100

Notes: Data from Compustat Global. Variables are discussed and defined in Table A-1: TA - total assets in million U.S dollar units; IK - ratio of investment to capital stock; SK - ratio of sales to capital stock; Cash - ratio of cash stock to total assets; CF - ratio of cash - flow to capital stock; LEV – leverage is ratio of total debt to total assets.

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Table 4: Energy Price Ratio for European Countries (Energy / CPI) 2000=100

Country	Code	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Austria	AUT	0.964	0.952	0.907	0.890	0.903	0.946	0.964	0.921	0.918	1.000	0.980	0.936	0.932	0.974	1.052	1.107
Belgium	BEL	0.959	0.914	0.913	0.897	0.876	0.909	0.925	0.881	0.887	1.000	0.984	0.933	0.916	0.960	1.051	1.121
Switzerland	CHE	0.896	0.829	0.847	0.829	0.836	0.863	0.888	0.834	0.853	1.000	0.978	0.921	0.928	0.965	1.058	1.126
Germany	DEU	0.963	0.954	0.916	0.919	0.893	0.886	0.894	0.854	0.884	1.000	1.047	1.032	1.063	1.088	1.186	1.277
Denmark	DNK	0.895	0.856	0.831	0.815	0.815	0.855	0.866	0.861	0.899	1.000	0.993	0.990	0.976	0.984	1.044	1.085
Spain	ESP	0.965	0.963	0.978	0.971	0.961	0.963	0.961	0.901	0.908	1.000	0.957	0.923	0.909	0.930	0.995	1.046
Finland	FIN	0.875	0.874	0.950	0.916	0.827	0.909	0.915	0.889	0.911	1.000	0.957	0.934	0.973	1.012	1.079	1.128
France	FRA	0.946	0.907	0.901	0.897	0.897	0.922	0.931	0.898	0.897	1.000	0.973	0.939	0.941	0.964	1.047	1.102
United Kingdom	GBR	0.878	0.864	0.878	0.895	0.897	0.900	0.912	0.902	0.935	1.000	0.963	0.941	0.954	1.003	1.096	1.241
Ireland	IRL	1.018	0.964	0.950	0.933	0.915	0.935	0.951	0.922	0.926	1.000	0.925	0.912	0.914	0.971	1.072	1.116
Italy	ITA	1.201	1.155	1.144	1.142	1.139	0.967	0.961	0.926	0.915	1.000	0.992	0.940	0.946	0.946	1.009	1.074
Netherlands	NLD	0.935	0.897	0.827	0.834	0.820	0.855	0.905	0.886	0.886	1.000	1.033	1.024	1.049	1.090	1.207	1.293
Norway	NOR	0.905	0.898	0.908	0.894	0.924	0.948	0.977	0.914	0.918	1.000	1.048	1.000	1.195	1.156	1.168	1.373
Portugal	PRT	1.225	1.145	1.110	1.077	1.037	1.025	1.038	1.016	0.969	1.000	1.014	0.982	0.997	1.026	1.104	1.163
Sweden	SWE	0.839	0.804	0.870	0.854	0.846	0.889	0.930	0.936	0.931	1.000	1.052	1.046	1.159	1.192	1.256	1.344

Notes: Data from OECD. Relative Price of Energy = CPI-Energy divided by CPI excluding food and energy prices.

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Table 5: Single Country Regressions, Non-financial Firm Investment Regressions with Energy Price Shocks (GMM-IV)

$$\frac{I}{K}_{it} = (\beta_{10} + \beta_{11}P_{c,t})\frac{I}{K}_{i,t-1} + (\beta_{20} + \beta_{21}P_{c,t})\frac{S}{K}_{i,t} + \beta_3 Cash_{i,t} + f_i + d_t + u_{i,t}$$

Notes: Variables are defined in Table A-1. I - investment, K - capital stock, S - sales, Cash - ratio of cash stock to total assets, $P_{c,t}$ - energy price (CPI-Energy/CPI exclusive of energy and food), f_i is an unobserved firm-specific effect, d_t denotes time dummies, and u_{it} is an error term and orthogonal to any available information on time t. Estimation is by GMM, time and fixed effects are removed by country-time and forward mean differencing prior to estimation. Instruments are first and second lags of I/K, S/K, Cash, CF, COGS (cost of goods sold scaled by prior periods capital stock) and industry dummies. In the weighted regression, weights are equal to a value of one divided by the number of observations per country. *P*-values for Hansen test of over-identifying restrictions. Heteroskedasticity adjusted standard errors in parentheses; ***,**, and * represent significance at 1%, 5%, and 10% respectively.

Model:	I/K_{it-1}	S/K_{it}	$Cash_{it}$	$I/K_{it-1}*P_{ct}$	Hansen H P-value	Number of observations
AUT	1.709 ***	0.011	-0.064	-1.424 ***	25.60	248
	(0.164)	(0.011)	(0.131)	(0.174)	(0.269)	
BEL	1.325 ***	0.019 ***	-0.566 ***	-1.277 ***	27.53	207
	(0.081)	(0.006)	(0.110)	(0.121)	(0.382)	
CHE	1.237 ***	0.008 *	0.024	-1.152 ***	32.64	545
	(0.224)	(0.004)	(0.090)	(0.268)	(0.112)	
DEU	1.113 ***	0.004	-0.141 ***	-1.045 ***	39.95	1733
	(0.208)	(0.006)	(0.116)	(0.216)	(0.189)	
DNK	1.310 ***	0.007	0.026	-0.941 ***	33.31	409
	(0.111)	(0.006)	(0.052)	(0.134)	(0.153)	
ESP	0.047	-0.013	-0.166	0.834 ***	24.82	263
	(0.161)	(0.010)	(0.138)	(0.204)	(0.416)	
FIN	1.210 ***	0.031 ***	0.191 ***	-1.053 ***	25.75	330
	(0.106)	(0.007)	(0.073)	(0.126)	(0.477)	
FRA	1.740 ***	0.014 ***	0.184 *	-1.545 ***	27.53	859
	(0.172)	(0.005)	(0.111)	(0.234)	(0.382)	
GBR	1.139 ***	0.010 **	-0.007	-0.691 ***	51.97	3010
	(0.186)	(0.004)	(0.066)	(0.220)	(0.014)	
ITA	1.532 ***	0.042 ***	0.053 *	-1.215 ***	22.30	624
	(0.059)	(0.002)	(0.053)	(0.087)	(0.672)	
NLD	1.301 ***	0.005 *	-0.111 ***	-1.219 ***	22.93	526
	(0.153)	(0.002)	(0.043)	(0.142)	(0.238)	
NOR	1.627 ***	-0.001	-0.069	-1.152 ***	26.06	191
	(0.103)	(0.003)	(0.060)	(0.097)	(0.460)	
SWE	1.020 ***	0.033 ***	-0.256 **	-0.819 ***	25.30	286
	(0.171)	(0.008)	(0.125)**	(0.124)	(0.558)	
IRE	1.600 ***	0.008 ***	-0.077	-1.128 ***	19.04	188
	(0.138)	(0.002)	(0.115)	(0.102)	(0.454)	
PRT	1.875 ***	-0.020	0.448 **	-1.557 ***	00.00	49
	(0.010)	(0.015)	(0.204)	(0.042)	(1.000)	
Median				-1.152		

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Table 6: Weighted Firm Investment Regressions for 15 European Countries with Energy Price Shocks (GMM-IV)

$$\frac{I}{K}_{it} = (\beta_{10} + \beta_{11}P_{c,t})\frac{I}{K}_{i,t-1} + (\beta_{20} + \beta_{21}P_{c,t})\frac{S}{K}_{i,t} + \beta_3 Cash_{i,t} + f_i + d_{c,t} + u_{i,t}$$

Notes: Variables are defined in Table A-1. I - investment, K - capital stock, S - sales, Cash - ratio of cash stock to total assets, $P_{c,t}$ - energy price (CPI-Energy/CPI exclusive of energy and food), f_i is an unobserved firm-specific effect, $d_{c,t}$ denotes country-time dummies, and u_{it} is an error term and orthogonal to any available information on time t. Estimation is by GMM, country-time and fixed effects are removed by country-time and forward mean differencing prior to estimation. Instruments are first and second lags of I/K, S/K, Cash, CF, COGS (cost of goods sold scaled by prior periods capital stock) and industry dummies. In the weighted regression, weights are equal to a value of one divided by the number of observations per country. *P*-values for *J*-statistic (test of over-identifying restrictions) are obtained using χ^2 distribution or Bootstrap simulation with 200 repetitions (the χ^2 p-value is not available for weighted regressions). Heteroskedasticity adjusted standard errors in parentheses; ***,**, and * represent significance at 1%, 5%, and 10% respectively.

	All non-financial firms			Firms in Manufacturing		
Model:	1	2	3	4	5	6
I/K_{it-1}	1.511***	0.384***	1.500***	1.903***	0.252***	1.791***
	(0.162)	(0.039)	(0.163)	(0.219)	(0.046)	(0.212)
S/K_{it}	0.012**	0.053***	0.012	0.028***	0.107***	0.043*
	(0.006)	(0.016)	(0.015)	(0.007)	(0.023)	(0.022)
$Cash_{it}$	0.029	0.193***	0.037	-0.164*	0.059	-0.145*
	(0.065)	(0.064)	(0.066)	(0.090)	(0.069)	(0.085)
$I/K_{it-1}*P_{ct}$	-1.243***		-1.225***	-1.932***		-1.788***
	(0.184)		(0.183)	(0.266)		(0.253)
$S/K_{it-1}*P_{ct}$		-0.026*	0.0003		-0.065***	-0.015
		(0.015)	(0.013)		(0.021)	(0.020)
Constant	-0.003**	-0.0001	-0.003*	-0.004**	-0.001	-0.003*
	(0.001)	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)
Number of obs.	8953	9051	8953	6115	6181	6115
Number of firms	1957	1980	1957	1327	1342	1327
Hansen P- value: Chi-square	N/A	N/A	N/A	N/A	N/A	N/A
Bootstrapped P-value for J-statistic:	0.957	0.118	0.968	0.958	0.218	0.953

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Table 7: Investment Regressions with Size and Business Cycle Effects (GMM-IV)

$$\frac{I}{K}_{it} = \beta_1 \frac{I}{K}_{i,t-1} + \beta_2 \frac{S}{K}_{i,t} + \beta_3 Cash_{i,t} + \beta_4 P_{c,t} \frac{I}{K}_{i,t-1} + \beta_5 Z_{i,t} \frac{I}{K}_{i,t-1} + \beta_6 P_{c,t} Z_{i,t} \frac{I}{K}_{i,t-1} + f_i + d_{c,t} + u_{i,t}$$

Notes: Variables are defined in Table A-1. I - investment, K - capital stock, S - sales, Cash - ratio of cash stock to total assets, $P_{c,t}$ - energy price (CPI-Energy/CPI exclusive of energy and food), f_i is an unobserved firm-specific effect, $d_{c,t}$ denotes country-time dummies, and u_{it} is an error term and orthogonal to any available information on time t. Z_{it} is either firm size, equal to the (log of) total assets in US dollars, or a business cycle dummy equal to one if recession in country c at time t, and equal to zero otherwise. Estimation is by GMM, country-time and fixed effects are removed by country-time and forward mean differencing prior to estimation. Instruments are first and second lags of I/K, S/K, Cash, CF, COGS, size or business cycle dummy, Con and industry dummies. P-values for J-statistic(test of over-identifying restrictions) are obtained using Bootstrap simulation with 200 repetitions. All the regressions are weighted regressions, weights are equal to a value of one divided by the number of observations per country. Heteroskedasticity adjusted standard errors in parentheses; ***,**,* represent significance at 1%, 5%, and 10% level respectively.

	Size Effect(non-financial firms) Z_{it} =log(TA_{it})			Business Cycle Effect Z_{it} =1 if recession, 0 otherwise		
Model:	1	2	3	4	5	6
I/K_{it-1}	0.613***	1.508***	1.493***	0.399***	1.475***	1.539***
	(0.068)	(0.159)	(0.159)	(0.051)	(0.152)	(0.160)
S/K_{it}	0.028***	0.012**	0.016**	0.029***	0.013**	0.020***
	(0.006)	(0.006)	(0.007)	(0.006)	(0.006)	(0.006)
$Cash_{it}$	0.140**	0.036	0.059	0.199***	0.061	0.129*
	(0.069)	(0.065)	(0.068)	(0.064)	(0.065)	(0.069)
$I/K_{it-1}*Z_{it}$	-0.045***	0.001	-0.148**	0.004	0.207***	-1.700***
	(0.012)	(0.012)	(0.066)	(0.065)	(0.065)	(0.538)
$I/K_{it-1}*P_{ct}$		-1.245***	-1.310***		-1.331***	-1.442***
		(0.198)	(0.200)		(0.187)	(0.198)
$I/K_{it-1}*P_{ct}*Z_{it}$			0.164**			1.989***
			(0.065)			(0.521)
Constant	-0.001	-0.003**	-0.003**	-0.001	-0.003***	-0.004***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Number of obs.	8953	8953	8953	8953	8953	8953
Number of firms	1957	1957	1957	1957	1957	1957
Bootstrapped P-value for J-statistic:	0.742	0.917	0.968	0.703	0.988	0.993

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Table 8: Investment Regressions with Asymetric Effects of Energy Prices (GMM-IV)

$$\frac{I}{K}_{it} = \beta_1 \frac{I}{K}_{i,t-1} + \beta_2 \frac{S}{K}_{i,t} + \beta_3 Cash_{i,t} + \beta_4 P_{c,t} \frac{I}{K}_{i,t-1} + \beta_5 W_{c,t} \frac{I}{K}_{i,t-1} + f_i + d_{c,t} + u_{i,t}$$

Notes: Variables are defined in Table A-1. I - investment, K - capital stock, S - sales, Cash - ratio of cash stock to total assets, $P_{c,t}$ - energy price (CPI-Energy/CPI exclusive of energy and food), f_i is an unobserved firm-specific effect, $d_{c,t}$ denotes country-time dummies, and u_{it} is an error term and orthogonal to any available information on time t. $W_{c,t}=1$ if $P_{c,t}-P_{c,t-1}>0$ and otherwise $W_{c,t}=0$. Estimation is by GMM, country-time and fixed effects are removed by country-time and forward mean differencing prior to estimation. Instruments are first and second lags of I/K, S/K, Cash, CF, COGS, size or business cycle dummy, Con and industry dummies. P-values for J-statistic(test of over-identifying restrictions) are obtained using Bootstrap simulation with 200 repetitions. All the regressions are weighted regressions, weights are equal to a value of one divided by the number of observations per country. Heteroskedasticity adjusted standard errors in parentheses; ***,**,* represent significance at 1%, 5%, and 10% level respectively.

	All non-financial firms				Firms in Manufacturing			
Model:	1		2		3		4	
I/K_{it-1}	0.545	***	1.484	***	0.506	***	2.125	***
	(0.058)		(0.177)		(0.083)		(0.222)	
S/K_{it}	0.032	***	0.016	**	0.037	***	0.023	***
	(0.007)		(0.006)		(0.007)		(0.007)	
$Cash_{it}$	0.164	**	0.043		0.037		-0.184	**
	(0.071)		(0.066)		(0.077)		(0.089)	
$I/K_{it-1}*P_{ct}$	-		-1.144	***	-		-2.276	***
			(0.214)				(0.306)	
$I/K_{it-1}*W_{ct}$	-0.377	***	-0.175	*	-0.420	**	0.181	
	(0.124)		(0.096)		(0.160)		(0.160)	
Constant	-0.0004		-0.002	*	-0.001		-0.004	**
	(0.001)		(0.001)		(0.002)		(0.002)	
Number of obs.	8953		8953		6115		6115	
Number of firms	1957		1957		1327		1327	
Hansen P-value: Chi-square	N/A		N/A		N/A		N/A	
Bootstrapped P-value for J-statistic:	0.823		0.963		0.802		0.963	

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Table 9: Weighted Firm Investment Regressions with Energy Price Shocks and Leverage Ratio (GMM-IV)

$$\frac{I}{K}_{it} = (\beta_{10} + \beta_{11} P_{c,t}) \frac{I}{K}_{i,t-1} + (\beta_{20} + \beta_{21} P_{c,t}) \frac{S}{K}_{i,t} + \beta_3 Cash_{i,t} + Lev_{i,t} + f_i + d_{c,t} + u_{i,t}$$

Notes: Variables are defined in Table A-1. I - investment, K - capital stock, S - sales, Cash - ratio of cash stock to total assets, $P_{c,t}$ - energy price (CPI-Energy/CPI exclusive of energy and food), f_i is an unobserved firm-specific effect, $d_{c,t}$ denotes country-time dummies, and u_{it} is an error term and orthogonal to any available information on time t. $Lev_{i,t}$ -leverage ratio, measured by total debt over total assets. Estimation is by GMM, country-time and fixed effects are removed by country-time and forward mean differencing prior to estimation. Instruments are first and second lags of I/K, S/K, Cash, CF, COGS (cost of goods sold scaled by prior periods capital stock) and industry dummies. In the weighted regression, weights are equal to a value of one divided by the number of observations per country. *P*-values for *J*-statistic (test of over-identifying restrictions) are obtained using χ^2 distribution or Bootstrap simulation with 200 repetitions (the χ^2 p-value is not available for weighted regressions). Heteroskedasticity adjusted standard errors in parentheses; ***,**, and * represent significance at 1%, 5%, and 10% respectively.

	All non-financial firms			Firms in Manufacturing		
Model:	1	2	3	4	5	6
I/K_{it-1}	1.320 ***	0.296 ***	1.237 ***	1.874 ***	0.202 ***	1.665 ***
	(0.187)	(0.032)	(0.185)	(0.238)	(0.037)	(0.225)
S/K_{it}	0.025 ***	0.059 ***	0.031 *	0.030 ***	0.123 ***	0.069 ***
	(0.007)	(0.017)	(0.017)	(0.007)	(0.025)	(0.022)
$Cash_{it}$	0.009	0.172 **	0.023	-0.206 **	0.023	-0.178 **
	(0.078)	(0.074)	(0.077)	(0.094)	(0.088)	(0.083)
$I/K_{it-1}*P_{ct}$	-1.168 ***	-	-1.063 ***	-2.008 ***	-	-1.747 ***
	(0.219)		(0.215)	(0.291)		(0.272)
$S/K_{it-1}*P_{ct}$	-	-0.028 *	-0.009	-	-0.081 ***	-0.040 **
		(0.016)	(0.016)		(0.023)	(0.019)
Lev_{it}	-0.101 *	-0.220 ***	-0.107 *	-0.100	-0.276 ***	-0.133 *
	(0.059)	(0.053)	(0.058)	(0.077)	(0.070)	(0.073)
Constant	-0.003 **	-0.0001	-0.003 *	-0.005 **	0.001	-0.003
	(0.001)	(0.001)	(0.002)	(0.002)	(0.002)	(0.002)
Number of obs.	8944	9041	8944	6112	6177	6112
Number of firms	1956	1978	1956	1327	1341	1327
Hansen P-value: Chi-square	N/A	N/A	N/A	N/A	N/A	N/A
Bootstrapped P-value for J-statistic:	0.897	0.052	0.892	0.933	0.228	0.912

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Appendix: Data and Sample Selection

Table A-1: The Construction of Financial Variables

Variable	Acronym	Definition	Compustat Data Item
Total Assets	TA	Total assets at the beginning of the period	DATA89
Capital stock	K	Net Property, Plant and Equipment.	DATA76
Total Debt	TD	Debt in current liability + Long-term debt	DATA94+DATA106
Cost of good sold	COGS	Cost of good sold scaled by the capital stock lagged one period	DATA4/DATA76 lagged
Leverage ratio	LEV	The ratio of Total Debt to Total Assets	DATA94+DATA106/DATA89
Cash Stock	Cash	Cash and equivalents scaled by total assets	DATA60/DATA89
Cash Flow	CF	Income Before Extraordinary Items + Depreciation and Amortization scaled by capital stock	(DATA32+DATA11)/DATA76
Net Sales/Capital	SK	Net sales at the end of period t-1. Scaled by capital.	DATA1/DATA76
Investment	I	Net Capital Expenditure	DATA 145
Investment/Capital	IK	Investment scaled by the capital stock lagged one period	DATA 145/ DATA76 lagged

Notes: Data from Compustat Global industrial/commercial and issue files; General rules with regard to the data are the following. We focus on non-financial firms (with SIC less than 6000). Firm-level data is eliminated if a firm has three or less years of coverage, if there are missing values for investment, capital stock, sales, cash stock, and cash flow, and if there are observations with negative values for assets, sales, or capital stock. In addition, we follow Gilchrist and Himmelberg (1998) and Love (2003) in excluding observations with IK > 2.5, SK > 20, cash > 0.6, and outliers in the top and bottom 1% of the variable values.

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