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by

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ABSTRACT

This paper investigates the effect of different types of productivity uncertainty on the delay of aggregate investment. The results of the model show that for risk–neutral competitive firms with constant returns to scale, the negative relation between uncertainty and aggregate investment exists in the case of aggregate uncertainty — Iwhen all firms in the industry face shocks to their productivity (like an oil shock), as in the case of relative uncertainty or when only some firms face those shocks (for instance adopting an innovation). The answer to the question, of which type of uncertainty leads to more delay of investment as a whole is ambiguous and depends two opposite effects which are determined by three parameters: the strength of the productivity shock, the elasticity of demand for output and the capital share in production. Assuming values of capital share which are consistent with empirical evidence (20-40 percent), the result is that there is more delay of investment under relative uncertainty than under the aggregate uncertainty. This result and the negative relationship between aggregate investment and productivity uncertainty are supported by the empirical evidence based on panel data of firms in the Israeli manufacturing industries in the first half of the 1990s.

Key words: irreversible investment, productivity shocks, aggregate and relative uncertainty.

JEL: C33, E22, D80, L60, O47

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Introduction

Economic theory has much to say about the relationship between uncertainty and investment. Most studies find that uncertainty (from different sources) has a negative effect on current investment. However, an important question that has not been discussed in the literature is whether the overall effect of uncertainty on investment depends on the type of uncertainty. In this study we try to answer this question by comparing the effect of uncertainty within an industry (when only some of the firms in the industry adopt ann innovation) to the effect of uncertainty between industries (when all firms in the industry face a productivity shocks like an increase in the oil price).

This paper uses a simple model of competitive equilibrium to describe the effect of different types of uncertainty on the delay of aggregate investment. Assuming investment is irreversible we can show in this theoretical framework that uncertainty over future productivity of firms has a negative effect on aggregate investment. This negative effect exists even when only some of the firms in the industry face shocks to their productivity. Furthermore, in order to find out in which type of uncertainty there is more delay of investment we have to examine the expected marginal profit of capital in both types of uncertainty. In this regard there are two effects: the price effect and the productivity effect, that determine the expected marginal profit of capital. The price effect increases the plausible range of values of the parameters in which the expected marginal profit of capital will be lower in the relative uncertainty case than in the aggregate uncertainty case, while the productivity effect operates in the opposite direction.

The answer to the question above therefore depends on these two effects, which drive from three parameters: the strength of the productivity shock, the elasticity of demand and the capital share in production. Lower demand elasticity increases the importance of the price effect, and increases the plausible range of parameters in which investment under relative uncertainty will be lower than under aggregate uncertainty. In this respect decreasing the strength of the productivity shock or increasing the capital share decreases the importance of the productivity effect, and hence increases also the plausible range of parameters for which there is more delay of investment in the relative, than in the aggregate uncertainty. Using a numeric solution it can be shown that if we assume that the capital share is in the range of 0.2-

0.4 (suitable to the capital share calculated for industries referred to in the empirical section), we get that for any value of elasticity demand and for productivity shocks of less than 20 percent there is more delay of investment under relative uncertainty than under aggregate uncertainty. Note that productivity shocks in the model determine the annual rate of change of the total factor productivity (TFP), which in the empirical data is less then 20 percent.

One possible explanation for this result is that while in the case of aggregate uncertainty the firm is protect from the effect of competition within an industry, this is not the case for uncertainty within an industry (relative uncertainty). Hence, for a given level of uncertainty, the effect within industry exceeds the effect between industries.

This study presents two different sets of panel dataof firms in the Israeli manufacturing industries in 1990s: Panel A contains information from the annual accounts of 215 Israeli industrial firms that were traded in the Tel-Aviv stock exchange in 1990-97. Panel B contains information on 2230 Israeli industrial firms (plants) with five or more employees for the years 1990-94.

The empirical evidence based on panel-data regressions shows a negative relationship between aggregate investment and uncertainty, even after controlling for liquidity constraints. In this respect the negative relationship between uncertainty and investment is not only due to the possibility that uncertainty is actually a proxy for credit constraints, since riskier firms are more likely to be credit constrained.

The empirical result from the second panel-data (panel B) regressions also supports our main finding from the model, that aggregate investment is smaller in case of relative uncertainty than under aggregate uncertainty, since firms are more likely to postpone investment under relative uncertainty——increasing 10 percent of the expected variance of the yearly change in TPF across firms will reduce the ratio of the mean of equipment investment to output by one percent under aggregate uncertainty, while under relative uncertainty it will be reduced by 1.8 percent.

In the next section of the paper we present the model and solve it for the certainty case and for the two other cases covering aggregate and relative uncertainty. In section 3 we describe the two panel-data sets that we use, and provide some empirical evidence in light of our results from the theoretical framework. Finally, in section 4 we set concluding remarks. Before we proceed, we briefly survey related literature.

1.1 A Brief Literature Review

One major line in the research literature, initiated by Hartman (1972) and followed by Abel (1983) argues that greater uncertainty will increase the investment of a risk –neutral competitive firm. Given constant return to scale in production, the marginal value product of capital is a convex function of the uncertain price faced by the firm so that, greater uncertainty raises the marginal valuation of one additional unit of capital thereby increasing investment.

Roberts and Weitzman (1981) show that if a firm has the option to abandon a project, then an increase in uncertainty increases the incentive to invest. Bar-Ilan and Strange (1982) find a similar effect in a model with costly entry and exit and time to build. Stiglitz and Weiss (1981) claim that uncertain projects are more desirable since bankruptcy limits downside risk.

Another line in the literature emphasizes the role of irreversibility in firms' investment decisions. Bernanke (1983), Mcdonald and Siegel (1986), Bertola (1988) and Dixit and Pindyck (1994) have shown that if risk neutral monopolistic firms cannot dispose of installed capital, greater uncertainty about future demand reduces current investment. Basically in an uncertain environment irreversibility increases the value of waiting for at least part of the uncertainty to be resolved and leads to postponing investment. In other words, if investment is irreversible there is an opportunity cost of investing in the current period. This cost increases with uncertainty hence lowers current investment. In this respect the capital asset pricing model (CAPM) as presented by Craine (1988) argues also that, greater uncertainty tends to make investment less desirable. Unlike the CAPM, however, uncertainty has a direct effect on investment in the models with irreversible investment –one that is independent of the correlation of investment with the market as whole (or the investment's risk).

Abel and Eberly (1995) find that in the long run even in the presence of irreversibility, uncertainty has two opposite effects on investment if the firm operates in competitive markets: (1) The user-cost effect - an increase in the variance of the shocks facing the firm tends to increase the user cost hence reducing current capital stock; (2) The irreversibility constraint i.e the disability to sell capital in bad times tends to increase the firm's capital stock (the hangover effect). Another factor that makes the investment-uncertainty relation ambiguous is investment lags. Bar-Ilan and Strange (1996) show, that with uncertain demand, time to build or construction lags firms tend to speed up capital accumulation to avoid facing high demand with too low stock of capital.

Caballero (1991) emphasizes the trade off between asymmetry in adjustment costs (i.e the degree of irreversibility) and imperfect competition. This trade off can be described as follows: given imperfect competition, the investment-uncertainty relationship is more likely to be negative as the degree of irreversibility increases; given the degree of irreversibility the relationship between investment and uncertainty is more likely to be negative as the firms become less competitive.

Assumptions about the firm's technology may also have a decisive role. Assuming decreasing returns to scale, Hartman (1976) shows that if labor can be flexibly chosen after demand has been observed, greater uncertainty can decrease investment if the elasticity substitution between labor and capital is sufficiently high. The intuition is that with enough substitutability higher uncertainty decreases the optimal capital input since little is lost by waiting until the uncertainty is resolved and labor is hired.

Pindyck (1993) shows how industry wide uncertainty can have a negative effect on aggregate irreversible investment (at the industry level), even when firms are perfectly competitive and have constant returns to scale.

Although there is a long-standing theoretical debate on the effects of uncertainty on investment,[1] so far there have been few empirical studies on the matter. This is not surprising in light of the many difficulties that this study raises. Models of uncertainty and investment often do not have closed –form solutions; micro-level data with rich information, that make it possible to test some of the theoretical predictions are not usually available; uncertainty and the degree of irreversibility are not in general observable.Thus, in most studies, indirect indicators are used, and measurement problems arises.

Caballero and Pindyck (1993) and Pindyck and Solimano (1993) use industry-level data to test the empirical relevance of models of irreversible investment. Under

[1]The debate goes back to the early 1970s with the studies of Sandmo (1971) and Leland (1972) look at the effect of uncertainty on output choice of a risk-averse firm; Hartman (1972) extend the analysis to a risk neutral firms operating in perfect competition.

irreversibility conditions firms invest only if the marginal return on capital exceeds a given threshold, which itself rises with uncertainty. The authors find a positive correlation between different measures of the threshold and the variance of the marginal return on capital, which is used as a proxy for uncertainty.

Ferderer (1993a) relies on the proportionality between the risk premium and the variance of returns to derive a measure of uncertainty from data on the term structure of the interest rates, finding that this measure has a negative effect on producers' durable equipment expenditure. In another paper Ferderer (1993b) reached a similar conclusion using data on macroeconomic forecasts made by financial institutions and non-financial firms, that participated in a monthly survey (Blue Chip survey).This conclusion remained significant even after controlling for user cost and Tobin's-q[2]. Ferderer used the standard deviation of these point expectations in the survey to measure uncertainty. In this respect uncertainty has the advantage of being forward –looking.

A negative relation between investment and macroeconomic shocks has been found in studies that focus on cross-section data of major developing countries (Aizemman & Marion, 1993,1995), as well on studies that investigated investment-uncertainty relationship at the firm level (Leahy and Whited, 1995). In this last study the authors used panel data of 600 U.S manufacturing firms over the period 1981-1987. Leahy and Whited created ex-ante volatility measures based on GARCH models and forecasts of variance from a vector autoregression technique as well as ex-post actual volatility measures. For all of these measures of uncertainty was found to have a negative effect on firm's investment, while no evidence was found for the presence of a CAPM effect of risk. These results are consistent with theories of irreversible investment.

[2]Leahy (1993) got a similar result, but in many other studies such as Leahy and Whited (1995) uncertainty effects investment only through Tobin's q.

2 The Theoretical Framework

2.1 The Model

We construct a model that allows the investigation of the effect of different types of uncertainty on the delay of aggregate investment. In particular our model shows how uncertainty over the future productivity of firms at the firm level and at the industry-wide level can have a negative effect in both cases on the aggregate (irreversible) investment, when firms are perfectly competitive. This negative effect at the industry level holds also for uncertainty over future output prices as well demonstrated by Pindyck (1993). Uncertainty of firms at the firm level over the future productivity of firms in perfect competition affects also negatively on the aggregate investment. Furthermore, in this model we get that for reasonable values of capital share in production, there is more delay of aggregate investment, when only some of the firms face shocks to their productivity (henceforth relative uncertainty), than for cases where this uncertainty is for all firms in the industry (henceforth aggregate uncertainty).

The model assumes a competitive equilibrium (Pindyck (1993), Caballero (1991)). Let *N* be a large number firms of an equal size in the industry, so that each takes the price as given. Let Q_t be the total output in the industry in this period. $Q_t = Nq_{it}$ where q_{it} is the output of firm *i* in period *t*. Each firm exists two periods. Within the two periods there is no depreciation of capital or discounting. Firms determine the level of investment at the beginning of each period. The production function is Cobb-Douglas with constant returns to scale for each firm *i* as follows:

$$q_{it} = Al_{it}^{\alpha} k_{it}^{1-\alpha} Z_{it} \quad 0 < \alpha < 1 \quad \text{i} = 1.....\text{N} \quad , \text{t} = 1,2 \qquad (1)$$

l_{it} is the labor input of firm *i* in period t, α is the elasticity of labor input, *A* is constant and k_{it} is the capital stock of firm *i* at the end of period *t*, so the investment of the firm is $i_{it} = k_{it} - k_{it-1}$. Investment is irreversible so $i_{it} \geq 0$. Z_{it} is a stochastic process that captures shocks to firm productivity (alternatively it could capture shocks to prices of intermediate inputs). For simplicity we assume that in the certainty case $Z_t = 1$ for all t. In the case of uncertainty $Z_{i1} = 1$ in period 1 only. In the second period Z_2 equals θ (where $1 < \theta \leq 2$) in the case of a positive shock to productivity and $2 - \theta$ in the case of a negative shock. Positive and negative shocks to productivity occur with equal probabilities. Notice that when θ increases the variance of the shock increases. A special case is $\theta = 2$. In this case one gets the same stochastic process as in Pindyck (1993). Firms are risk neutral, they have rational expectations and they know at the beginning of period 2, prior to their second investment decision what the realization of the shock is in the period considered. The demand for output in the industry is:

$$P_t = Q_t^{-\frac{1}{\varepsilon}} \tag{2}$$

Where ε is the constant elasticity of demand and P_t is the output price in the industry in period *t*. We assume that $\varepsilon > 1$ so there are no capacity constraints. The operating profit function $\prod_{it}$ for each firm in period *t* is then:

$$\prod_{it} = P_t \mathrm{q}_{\mathrm{it}} - \mathrm{Wl}_{\mathrm{it}} \tag{3}$$

W is the nominal wage per unit of labor and assumed to be fixed over time and firms[3].

Substituting the optimal size of l_{it} in equation (3) from the marginal profitability of labor and rearranging it, leads to:

$$\prod_{it}(K_{it}) = hP_t^{\eta} \mathrm{Z}_{\mathrm{it}}^{\eta} \, \mathrm{k}_{\mathrm{it}} \quad \text{where} \tag{4}$$

$$\mathrm{h} = (1 - \alpha)\mathrm{A}^{\eta} \left(\frac{\alpha}{\mathrm{W}}\right)^{\frac{\alpha}{(1-\alpha)}} \text{ is constant and positive.}$$

$$\eta = \frac{1}{(1 - \alpha)} > 1$$

In a similar way we can express the production function and obtain:

$$q_{it} = \frac{h}{(1-\alpha)} \mathrm{P}_{\mathrm{t}}^{\alpha\eta} \mathrm{Z}_{\mathrm{it}}^{\eta} \mathrm{k}_{\mathrm{it}} = \mathrm{BP}_{\mathrm{t}}^{\alpha\eta} \mathrm{Z}_{\mathrm{it}}^{\eta} \, \mathrm{k}_{\mathrm{it}} \tag{5}$$

[3]Even when labor is not employed in our industry the wage for those labor units in other industries remains the same W.

Where $\mathrm{B} = h/(1-\alpha)$. Note from equation (4) that in a profit maximizing equilibrium the value of a marginal unit of capital is $hP_t^{\eta} Z_{it}^{\eta}$ regardless of the firm capital stock (i.e. the elasticity of the demand for capital in the long run is infinite). This value is convex in P_t and in Z_t , so its expectation is increased by a mean preserving spread in P_t (or Z_t) but as shown later this does not mean that uncertainty leads the firm to invest more.[4]

Firms have two options to buy a unit of capital- (a) in period 1 at a cost of P_k^1 , capital that serves the firms for two periods. (b) in period 2 at a cost of P_k^2 , capital that serves the firms only for period 2 . We assume also that the costs of a unit of capital in both periods are exogenous, positive and constant in any state of nature and that $P_k^1 > P_k^2 = 0.5P_k^1$. Price and industry output are endogenous and will be determined in a competitive equilibrium, where each firm takes the output price as given and wishes to invest until the point that the value of marginal profitability of capital equals to the cost of a unit of capital. We can now find what the price and industry output are in each period, and for each state of nature. In this way we can compare the level of investment in the three following cases:

(I) The certainty case (henceforth ***cert***) where $Z_{it}=1$ for all firms in all t.

(II) The case of aggregate uncertainty (henceforth ***aguc***) where all firms in the industry face the same stochastic process of productivity as explained above, so $Z_{1t}=Z_{2t}=...=Z_{Nt}$.

(III) The relative uncertainty case (henceforth ***reuc***) where only some firms face the stochastic process Z_{it} to their productivity and the other type of the firms in the industry have no shocks to productivity. In this case we assume firms know ex-ante what type they are. We assume that the share of the firms that face productivity shocks in the total number firms in the industry is γ where $0<\gamma<1$. Hence, $1-\gamma$ firms in the industry do not face productivity shocks at all. Notice that the level of

[4] Hartman (1972) and Abel (1983) first demonstrated this result of a positive relation between uncertainty over future output prices and investment.

investment for this later type of firms depends on the realization of the shocks of firms of the first type (hence relative uncertainty).

2.2 The Certainty Case (cert)

In the certainty case $P_1 = P_2$ and all investment occurs in period 1.We also assume $P_k^2 = 0.5P_k^1$. Each firm invests an infinite amount if $2hP_1^\eta Z_{i1}^\eta > P_k^1$ and invests nothing if $2hP_1^\eta Z_{i1}^\eta < P_k^1$. Thus, in equilibrium firms invest until the price falls to the point that $2hP_1^\eta Z_{i1}^\eta = P_k^1$. Since $Z_{it} = 1$ we get $P_1 = P_2 = \left[\frac{P_k^1}{2h}\right]^{1/\eta}$. Industry output in the first period is $Q_1 = [\frac{2h}{P_k^1}]^{\varepsilon/\eta}$. From equation (5) we can find industry investment in period 1: $I_1^{cert} = K_1^{cert} = \frac{1}{B}\left[\frac{2h}{P_k^1}\right]^{\alpha+\varepsilon(1-\alpha)} = \frac{1}{B}\left[\frac{2h}{P_k^1}\right]^{\Delta}$ where $\Delta = \alpha + \varepsilon(1-\alpha) > 1$ since $\varepsilon > 1$.

2.3 The Aggregate Uncertainty Case (*aguc*)

In this case the realizations Z_t for t=2 are unknown to all firms when they invest in period 1.We are interested in the level of investment in period 1. This problem is solved backwards. We keep the assumption that $P_k^2 = 0.5P_k^1$. In period 2 if we have a positive shock to productivity $Z_2^p = \theta$ then the output price P_2^{P} is derived from:

$hP_2^\eta Z_2^\eta = P_k^2$, so we get $P_2^{\mathrm{P}} = \frac{1}{\theta}\left[\frac{P_K^2}{h}\right]^{1/\eta}$. The output is derived from the demand function: $Q_2^{\mathrm{P}} = [\frac{h}{P_k^2}]^{\varepsilon/\eta}\theta^{\varepsilon}$. The industry capital stock in period 2 in a good state is:

$K_2^p = \frac{1}{B}\left[\frac{h}{P_k^2}\right]^{\Delta}\theta^{\varepsilon-1}$ and since $P_k^2 = 0.5P_k^1$, $K_2^p = \frac{1}{B}\left[\frac{2h}{P_k^1}\right]^{\Delta}\theta^{\varepsilon-1}$. If we have a negative shock to productivity, then $Z_2^{\mathrm{N}} = 2-\theta$ and we get that in equilibrium $K_2^{\mathrm{N}} < K_1$.

Since investment is irreversible it implies that $I_2^{\mathrm{N}}=0$ we solve the problem for period 1 and period 2 together taking into account that $K_2^{\mathrm{N}}=K_1$. In period 1 each firm invests until the expected value of a unit capital equals its cost:

$hP_1^{\eta}Z_1^{\eta}+E_1[hP_2^{\eta}Z_2^{\eta}]=P_k^1$, where E_1 is the expectation operator conditional on information available in period 1. Since in a positive shock to productivity we get $hP_2^{\eta}Z_2^{\eta}=P_k^2$ then:

$hP_1^{\eta}Z_1^{\eta}+0.5P_k^2+0.5h(P_2^N)^{\eta}(2-\theta)^{\eta}=P_k^1$. The output price in the industry in period 1 is $P_1=\left[\frac{P_k^1}{2h}\right]^{1/\eta}[1/(0.67+0.33(2-\theta)^{(\varepsilon-1)/\Delta})]^{1/\eta}$ and the total output in the industry is $Q_1=[\frac{2\mathrm{h}}{\mathrm{P_k^1}}]^{\varepsilon/\eta}[0.67+0.33\,(2-\theta)^{(\varepsilon-1)/\Delta}]^{\varepsilon/\eta}$. We can also find investment in period 1 for the aggregate uncertainty case:

$$K_1=I_1^{\mathrm{aguc}}=\frac{1}{B}[\frac{2\mathrm{h}}{\mathrm{P_k^1}}]^{\Delta}[0.67+0.33\,(2-\theta)^{(\varepsilon-1)/\Delta}]^{\Delta}<\frac{1}{B}\left[\frac{2h}{P_k^1}\right]^{\Delta}=I_1^{\mathrm{cer}}\ .$$

Notice that the aggregate industry investment in period 1 would be higher in the ***certainty*** case, than in the ***aggregate uncertainty*** case. We get that investment in period 1 in the ***aguc*** case is lower than in the ***certainty*** case in spite of the convexity of the value of the marginal unit of capital in *P*. This result arises since the capital stock is not used in full capacity when a negative shock to productivity occurs. An alternative explanation following Pindyck (1993) argues that a mean preserving spread in Z_t reduces the expected value of the marginal profitability of capital, and the distribution of this future value is asymmetric in the uncertainty case. Since firms have rational expectations and investment is irreversible, they tend to reduce their investment in period 1 (compared to the level in the certainty case), and to invest in a later period if they face a good state[5]:

$$I_2^{\mathrm{p}}=K_2^{\mathrm{P}}-K_1=\frac{1}{B}\left(\frac{2h}{P_k^1}\right)^{\Delta}[\theta^{\varepsilon-1}-(0.67+0.33\,(2-\theta)^{(\varepsilon-1)/\Delta})^{\Delta}]$$

Since $\theta > 1$, then $I_2^{\mathrm{P}} > 0$ if $\varepsilon > 1$ [6].

The industry investment in a bad state is

$$: I_2^{\mathrm{N}} = K_2^{\mathrm{N}} - K_1 = 0 \quad .$$

2.4 The Relative Uncertainty Case (*reuc*)

In this case we have two types of firms in the industry: type *c* and type *s* with the same production function. The only difference between these two types is, that firms of type s face the stochastic process $Z_{\mathrm{S}\,t}$ to their productivity as shown earlier, while firms of type *c* in the industry have no shocks to their productivity $Z_{\mathrm{C}\,t} = 1$. As explained above the investment of firms of type *c* is also dependent on the realization of shocks of firms of type *s* (a sort of endogenous uncertainty). Let γ be the exogenous share of firms of type *s* in the overall number firms in the industry N. The aggregate capital stock in the industry is:

$\sum_{i=1}^{N} k_{i\,t} = \gamma N k_{\mathrm{S}t} + (1-\gamma) N \mathrm{k}_{\mathrm{C}\,t}$. Obviously if $\gamma = 0$ it would be the certainty case and if $\gamma = 1$ we get back to the aggregate uncertainty case, so we assume that $0 < \gamma < 1$. Since the value of the marginal profitability of capital for all firms in perfect competition $hP_t^{\eta} Z_{it}^{\eta}$ is independent of the capital stock, and the costs of unit capital is constant, we get a solution in which only firms of type s invest in period 2 if there is a positive shock to their productivity $()Z_{\mathrm{S}\,t} > Z_{\mathrm{C}\,t}$ for $t > 1$ .Since the cost of the capital P_k^2, and firms of type *s* are perfectly competitive they invest until $hP_S^{\eta} Z_S^{\eta} = P_k^2$. The output price in a good state is therefore below the marginal cost of firms of type *c*, so those firms will not invest but they produce in this good state using the capital stock from period 1.

We assume also that the capital stock of firms of type *c* can not be sold to other firms (firms of type *s* in the good state). A possible motivation to this last assumption is firm's imperfect information regarding the quality of the capital stock that another type of firm may wish to sell to it. An alternative explanation is high

[5] The expected marginal profit of capital is lower in the aguc case than in the certainty case

relocation costs among firms or assuming that each type of firms use capital with specific technology to produce the same product ("embodied technology"). If on the other hand, there is a negative shock to the productivity in period 2 only firms of type *c* will invest in this state. Firms of type *s* will not invest but they produce in this bad state using the capital stock from period 1. Assume also that firms of type *s* can not sell this capital stock to firms of the other type.

We assume that $\underline{\gamma}<\gamma<\bar{\gamma}$ where $\underline{\gamma}$ and $\bar{\gamma}$ are the minimum share of firms of type *s* and type *c* respectively that ensures an equilibrium of perfect competition. In order to find out the level of investment in each period we solve the problem backwards.

In period 2 in a good state output price P_2^{P} is derived from $hP_2^{\eta} Z_{S2}^{\eta} = P_k^2$ so $P_2^{\mathrm{P}} = \frac{1}{\theta}\left[\frac{P_k^2}{h}\right]^{1/\eta}$ and the total output in the industry $Q_2^{\mathrm{P}} = [\frac{\mathrm{h}}{\mathrm{P}_\mathrm{k}^2}]^{\varepsilon/\eta}\,\theta^{\varepsilon}$. Firms of type c will not invest but they will use the capital stock from period 1 and produce $(1\text{-}\gamma)\mathrm{N}\,\mathrm{q}_{\mathrm{c2}}^{\mathrm{p}}$.

In a similar way we can find that the price of the output in a bad state in period 2 is $P_2^{\mathrm{N}} = \left[\frac{P_k^2}{h}\right]^{1/\eta}$, and industry output is $Q_2^{\mathrm{N}} = [\frac{\mathrm{h}}{\mathrm{P}_\mathrm{k}^2}]^{\varepsilon/\eta}$. In period 1 firms of type *c* invest until: $hP_1^{\eta} Z_1^{\eta} + 0.5P_k^2 + 0.5h(P_2^p)^{\eta} = P_k^1$, so by assuming $P_k^2 = 0.5P_k^1$ we get $P_1 = \left[\frac{3P_k^1}{4h}\right]^{1/\eta}[1-0.33(\frac{1}{\theta})^{\eta}]^{1/\eta}$, while firms of type *s* invest until $hP_1^{\eta} Z_1^{\eta} + 0.5P_k^2 + 0.5h(P_2^N)^{\eta}(2-\theta)^{\eta} = P_k^1$ so for them we get $P_1 = \left[\frac{3P_k^1}{4h}\right]^{1/\eta}[1-0.33(2-\theta)^{\eta}]^{1/\eta}$ Since $(\frac{1}{\theta})^{\eta} > (2-\theta)^{\eta}$ for $1 < \theta < 2$ the output price in equilibrum is $P_1 = \left[\frac{3P_k^1}{4h}\right]^{1/\eta}[1-0.33(\frac{1}{\theta})^{\eta}]^{1/\eta}$ thus, only firms of type c invest in period 1 (firms of type s will not invest since there value of a marginal unit of capital is below

[6]In pindyck model (1993) the industry wide shock is on the demand side and we get similar results to our model for investment in first period, while investment in the second period in a good state in

the cost of a unit of capital). The industry output $Q_1=\left[\frac{h}{P_k^1}\right]^{\varepsilon/\eta}[1/(0.75-0.25(\frac{1}{\theta})^{\eta})]^{\varepsilon/\eta}$

and the total capital stock in the industry is $\sum_{I=1}^{N} k_{i1}=(1-\gamma)Nk_{C1}=\frac{1}{B}[\frac{h}{P_k^1}]^{\Delta}[1/(0.75-0.25(\frac{1}{\theta})^{\eta})]^{\Delta}$.

In period 2 The capital stock of all firms of type s in a good state is $\gamma Nk^{p}_{S2}=\frac{1}{B}\left[\frac{2h}{P_k^1}\right]^{\Delta}[\theta^{\varepsilon-1}-0.5^{\Delta}[1/(0.75-0.25(\frac{1}{\theta})^{\eta})]^{\Delta}\left[\frac{1}{\theta}\right]^{\eta}]$. We have to add to this size the total capital stock of firms c, $(1-\gamma)NK_{C1}$, therefore:

$$\sum_{i=1}^{N} k^{p}_{i2}=\frac{1}{B}\left[\frac{2h}{P_k^1}\right]^{\Delta}[\theta^{\varepsilon-1}-0.5^{\Delta}[1/(0.75-0.25(\frac{1}{\theta})^{\eta})]^{\Delta}\left[\frac{1}{\theta}\right]^{\eta}]+(1-\gamma)Nk_{C1}\quad .$$

In a bad state in period 2 the total capital stock in the industry is: $(1-\gamma)Nk^{N}_{C2}=\frac{1}{B}\left[\frac{2h}{P_k^1}\right]^{\Delta}$. Now we can compute from these results the aggregate investment in each period:

$$I_1^{\text{reuc}}=K_1=\frac{1}{B}\left[\frac{h}{P_k^1}\right]^{\Delta}[1/(0.75-0.25(\frac{1}{\theta})^{\eta})]^{\Delta}<\frac{1}{B}\left[\frac{2h}{P_k^1}\right]^{\Delta}=I_1^{\text{cer}}\ .$$

Note that like in the aggregate uncertainty case, in the relative uncertainty case each firm *c* or *s* sees in period 1 the asymmetric distribution of future values of the marginal profitability of capital. Firms of type *s* know ex-ante that they will not invest in the case of a negative shock to their productivity, and firms of type *c* will not invest in a state of positive shocks to productivity of firms of type *s*.

Aggregate investment of firms of type *s* (i.e. industry investment) in a good state in period 2 is therefore:

$$I_2^{\text{p}}=\sum_{i=1}^{N} k^{\text{P}}_{i2}-K_1=\gamma Nk^{p}_{S2}=\frac{1}{B}\left[\frac{2h}{P_k^1}\right]^{\Delta}[\theta^{\varepsilon-1}-0.5^{\Delta}[1/(0.75-0.25(\frac{1}{\theta})^{\eta})]^{\Delta}\left[\frac{1}{\theta}\right]^{\eta}]\ .$$

Note $I_2^{\text{p}}>0$ for $\varepsilon>1,\theta>1$. In the bad state industry investment in period 2 is positive:

pindyck model is positive for all values of ε.

$I_2^{\mathrm{N}} = \sum_{i=1}^{N} k_{i2}^{\mathrm{N}} - K_1 = \frac{1}{B}\left[\frac{h}{P_k^1}\right]^{\Delta} [2^{\Delta} - [1/(0.75 - 0.25(\frac{1}{\theta})^{\eta})]^{\Delta} > 0$ for all $1 < \theta < 2$ and only firms of type *c* invest. Note that in both cases (the good and the bad state), investment is positive.

2.5 Comparing Aggregate and Relative uncertainty

In order to find out in which type of uncertainty there is more delay of investment we have to examine the expected marginal profit of capital in both types of uncertainty. In this regard there are two effects: the "price effect" and the "productivity effect" that determine the expected marginal profit of capital . Firms of type c know that in period 1 they invest alone, but in the case of a positive shock to the productivity of firms of type *s* in period 2 the output price will be very low (compared to any prices in the aguc case). This "price effect" increases the range of the value of the parameters (henceforth range of parameters) of which, the expected marginal profit of capital will be lower in the relative uncertainty case, than in the aggregate uncertainty case. On the other hand there is a second effect ("productivity effect") working in the opposite direction, increasing the range parameters that, the expected marginal profit of capital will be higher in the relative uncertainty case than in the aggregate uncertainty case. The answer to the question in which uncertainty there is more delay of investments depends on these two effects, and is a result of the combination of three parameters: the strength of the productivity shock (θ), the elasticity of demand (ε) and the capital share in production ($1-\alpha$).

Decreasing of demand elasticity increases the importance of the price effect, and increases the plausible range parameters that, investment in the relative uncertainty will be lower, than in the aggregate uncertainty. In this respect decreasing the strength of the productivity shock (θ) or increasing the capital share decreases the importance of the "productivity effect", hence increases also the plausible range parameters to more delay of investment in the relative, than in the aggregate uncertainty.

Using a numeric solution it can be shown that if capital share is in the range of 0.2-0.4, if productivity shocks of less than 20 percent, then for any value of elasticity demand there is more delay of investment in the relative uncertainty, than in the aggregate uncertainty.

Note that (θ) is measures the annual rate of change of the total factor productivity (TFP), which is in the empirical data less then 20 percent.

Proposition 1 *whether firms postpone more investments in the relative uncertainty case than in the aggregate uncertainty case (i.e.* $I_1^{aguc} > I_1^{reuc}$, $I_2^{aguc} < I_2^{reuc}$*) depends on the relative importance of two opposite effects:*

1. *"price effect", that increases the possibility range that, investment in the relative uncertainty will be lower, than in the aggregate uncertainty.*
2. *"productivity effect", that increases the possibility range that, investment in the aggregate uncertainty will be lower, than in the relative uncertainty.*

Proof. In period 1 the difference between the aggregate investment in both cases of uncertainty depends on the difference between the expected marginal profit of capital of them:

$$E_1^{aguc}[hP_2^{\eta} Z_2^{\eta}] - E_1^{reuc}[hP_2^{\eta} Z_2^{\eta}] = 0.5P_k^2 + 0.5h\,(P_2^N)^{\eta}(2-\theta)^{\eta} - 0.5P_k^2 - 0.5h\,(P_2^P)^{\eta} = 0.5hx$$

Since h is positive, if x>0 than investment in the relative uncertainty will be lower, than in the aggregate uncertainty. The expression x is determined by two effects:

1) "productivity effect" : $(2-\theta)^{\eta} < 1$ since $1 < \theta < 2$, hence decrease possibility range that x is positive.

2) "price effect" : $P_2^{P,reuc} < P_2^{N,aguc}$ (See proof above), hence increase possibility range that x is positive.

We can prove that $P_2^{N,aguc} - P_2^{P,reuc}$ is positive, by writing the relevant expression in logarithmic form and rearranging we get:

$$\frac{1}{\eta}\ln\left(\frac{3(2\text{-}\theta)^{(\varepsilon-1)/\Delta}}{2+(2-\theta)^{(\varepsilon-1)/\Delta}}\right)-ln(2-\theta)+ln(\theta)=\frac{1}{\eta}\{\ln 3\text{-}\ln[(2+(2-\theta)^{(\varepsilon-1)/\Delta}]\}+$$

$$[\frac{\varepsilon-1}{\alpha\eta+\varepsilon}-1]ln(2-\theta)+ln(\theta)>0$$

since $\alpha\eta>0,\ 1<\theta<2$.

As noted before, decreasing of demand elasticity increases the importance of the price effect, and increases the plausible range parameters that, investment in the relative uncertainty will be lower, than in the aggregate uncertainty. In this respect decreasing the strength of the productivity shock (θ) or increasing the capital share will decrease the importance of the "productivity effect".

Proposition 2 *In the relative uncertainty for* $\varepsilon>1$ *increasing* θ *(i.e. the variance of the productivity shock), raises the size of uncertainty, hence firms postpone more investment.*

Proof. *We can prove this proposition by proving the two following lemmas (1, 2):*

Lemma 1 *In the relative uncertainty for* $\varepsilon>1$ *the aggregate industry investment increases in period 2 when* θ *rises in both the positive and the negative state.*

Proof. The aggregate industry investment in the relative uncertainty case in a positive state is:

$$I_2^{\text{p,reuc}}=\left(\frac{2h}{P_k^1}\right)^{\Delta}\frac{1}{B}[\theta^{\varepsilon\text{-}1}-0.5^{\Delta}[1/(0.75-0.25(\frac{1}{\theta})^{\eta})]^{\Delta}\left[\frac{1}{\theta}\right]^{\eta}]$$

$$\frac{\partial I_2^{\text{p,reuc}}}{\partial\theta}=\left(\frac{2h}{P_k^1}\right)^{\Delta}\frac{1}{\text{B}}[(\varepsilon-1)\theta^{\varepsilon\text{-}2}+0.5^{\Delta}\Delta[1/(0.75-0.25(\frac{1}{\theta})^{\eta})]^{\Delta+1}0.25\eta\left[\frac{1}{\theta}\right]^{2\eta+1}+$$

$$0.5^{\Delta}[1/(0.75-0.25(\frac{1}{\theta})^{\eta})]^{\Delta}\eta\left[\frac{1}{\theta}\right]^{\eta+1}>0,\quad \text{since}\ \varepsilon>1,\ \theta>1\ .$$

In the bad state we get that $I_2^{\mathrm{N}} = \left(\frac{h}{P_k^1}\right)^{\Delta} \frac{1}{\mathrm{B}}[2^{\Delta} - [1/(0.75 - 0.25(\frac{1}{\theta})^{\eta})]^{\Delta}]$ so

$$\frac{\partial I_2^{\mathrm{N,reuc}}}{\partial\theta} = \left(\frac{h}{P_k^1}\right)^{\Delta} \frac{1}{\mathrm{B}} \Delta 0.25\eta (\frac{1}{\theta})^{\eta+1} [1/(0.75 - 0.25(\frac{1}{\theta})^{\eta})]^{\Delta+1} > 0 .$$

lemma 2 *In the relative uncertainty, the aggregate industry investment decreases in period 1 when* θ *rises.*

Proof. The aggregate industry investment in the relative uncertainty case

In period 1 is: $I_1^{\mathrm{reuc}} = \left(\frac{h}{P_k^1}\right)^{\Delta} \frac{1}{B}[1/(0.75 - 0.25(\frac{1}{\theta})^{\eta})]^{\Delta}$ from this we get

$$\frac{\partial I_1^{\mathrm{reuc}}}{\partial\theta} = -\left(\frac{h}{P_k^1}\right)^{\Delta} \frac{1}{\mathrm{B}} \Delta [1/(0.75 - 0.25(\frac{1}{\theta})^{\eta})]^{\Delta+1} 0.25\eta \left[\frac{1}{\theta}\right]^{\eta+1} < 0 .$$

3 Empirical Evidence

3.1 The Data

In this section look for supporting empirical evidence to our claim that, for reasonable values of capital share, there is more delay in investment in cases of relative uncertainty than in the case of aggregate uncertainty.

Our null hypothesis is that there is a negative relationship between the mean of firms' investment and their expectation about next period's variance of investment in each industry.[7] Note that this variance could be outcome of: (1) Differences in the "nature" of productivity shocks in each industry: whether the productivity shocks are common to all firms (aguc in our theoretical model), or only part of firms in the industry face productivity shocks (reuc in our model). (2) Differences in the strength and variance of the productivity shocks in each industry (θ in the model). Thus, the negative relationship between the mean of firms' investment and their expectation about next period's variance of investment in each industry could be explained by this two sources of variance. Our data are based on two panels of data of firms in the manufacturing industries:

a) Panel A contains information on 215 Israeli industrial firms that were traded in

Table 1: Distribution of firms by industry, 1990-1997 (panel A)

industry	1990	1991	1992	1993	1994	1995	1996	1997
Total number of firms	144	192	209	225	229	238	239	238
Food and tobacco	20	26	28	29	29	29	28	27
Textiles and clothing	19	22	22	22	22	23	23	23
Metal products	25	30	31	32	33	34	34	33
machinery and electronic equipment	34	50	54	60	63	69	70	70
bulding products	11	12	12	12	12	12	12	12
chemical ,Rubber and plastic products	17	28	33	37	37	37	38	39
Wood,paper and printing products	11	15	19	22	22	22	22	22
other industries	7	9	10	11	11	12	12	12

the Tel-Aviv stock exchange for the years 1990-1997. The data are based on the annual accounts of the firms, and include series of investment in fixed assets and

[7] Obviously on need to control for other effects such as scale on these variables. Leahy & Whited (1995) used a similar relationship between investment and expected variance n -period a head in a firm level regression.

total income (sales) of those firms in the 8 main industries. All series are in fixed prices (1990 NIS), using CBS price deflators of consumer goods.

The firm level data include also information about the operating profit, liquid assets, the government investment subsidies, export share in income as well as firm characteristics (age, branch code), see Ber, Blass and Yosha (2001) for more details. The distribution of firms by industry and year are presented in Table 1.

b) Panel B used in this study contains information on 2230 Israeli industrial firms (plants), with 5 or more employees for the years 1990-1994. The data were extracted from the annual industrial survey carried out by the Central Bureau of Statistics (CBS) of Israel, and include data on production and total fixed investment (structure & equipment) of each firm in the 17 main industries at the 2 digit level[8]. The firm level data also include information about labor, export share

table 2: Distribution of firms by industry, 1990-1994 (panel B)

industry	1990	1991	1992	1993	1994
Total number of plants	2122	2186	2193	2290	2352
Mining and quarrying	34	36	36	37	38
Food, beverages, and tobacco	273	279	273	287	283
Textiles	87	83	82	81	89
Clothing and made-up textiles	222	223	215	229	233
Leather and its products	72	78	80	83	84
Wood and its products	125	132	135	139	143
Paper and its products	70	73	69	80	79
Printing and publishing	159	161	159	167	176
Rubber and plastic products	177	185	183	187	193
Chemical and oil products	90	87	88	93	99
Non metalic mineral products	96	103	109	104	111
Basic metal	39	39	40	38	42
Metal products	236	259	268	290	292
Machinery	99	91	94	100	106
Electrical and electronic equipment	193	200	203	212	220
Transport equipment	54	54	55	55	54
Miscellaneous	96	103	104	108	110

in production, the cost of equipment and building rentals, the deprecation on the net stock of capital as well as firm characteristics (age, branch code). See Griliches and Regev (1995) for more details and references. Naturally most of the firms in any given year are firms continuing in operation from the previous year,

[8] All series are originally in thousands of current dollars and converted to fixed prices (1990 NIS), using the average exchange rate NIS/DOLLAR and CBS price deflators of investment and production at the two-digit level.

but a substantial number of firms entered and exited the sample. In every year, about 7 percent of the firms cease to exit, while about 10 percent of the firms are newcomers (Table 2).

3.2 Estimation Results

The dependent variable is the mean of investment to income ratio (in panel A) and the mean of investment to output ratio (in panel B**) across firms for each industry and for each period**. The main right hand variable in the estimated equation is the expectation about next period's variance of this investment ratio across firms[9]. This normalization of investment controls for scale effects among industries that may cause a spurious positive relationship between the mean and the variance of firms' investment in each industry[10].

The other explanatory variables are also in means across firms for each industry and for each year. These variables are the conventional ones used in investment functions (such as "accelerator" activity, liquidity, profitability). All the regressions include year dummies to account for the time specific factors such as the increase in the investment ratio to output in the first years of the 1990s due the immigration wave from the former Soviet Union to Israel.

3.2.1 Results of the Small Panel (Panel A)

Using a panel for industries i=1….I and years t=1….T the estimated equation for panel A is of the form[11]:

$$MIY_{it} = \alpha_i + \beta_1 VAR\_IY_{i,t+1} + \beta_2 DY_{it} + \beta_3 GOV\_INV_{i,t-1} + \beta_4\ PROF_{i,t-1}$$
$$+ \beta_5\ LIQ_{it-1} + \beta_6 AGE_{it} + \varepsilon_{it}$$

where:

MIY = mean of investment (in fixed assets) to sales income ratio across firms.

VAR_IY= the expected variance of investment (in fixed assets) to income ratio across firms (one year ahead). Notice we assume rational expectation in the sense of

$$E_t(VAR\_IY_{i,t+1}) = VAR\_IY_{i,t+1}$$

[9]In panel B we use instead, the expected variance of the change in the total factor productivity (Solow residual) across firms for each industry with one year ahead.

[10]Alternatively we used the mean and the variance change rate of the firms' investment in order to control for scale and we got similar results.

[11] These regression based on similar regression for these panel data in Firm level (Bar, Blass& Yosha 2001).

DY= the mean of yearly percentage of change in the sales income ("acceleator" effects).

GOV_INV= the mean of the share of government subsidies out of investment in fixed assets (with a one year lag, in percentage).

PROF= the mean of the share of operating profit out of total sales income (with a one year lag).

LIQ= the mean of liquid assets out of total assets (with one year lag).

AGE= the mean of the age firms in each industry and in each year.

The unbalanced panel A covers 8 industries over the period 1990-1997 and about 215 firms.

Table 3 presents the results for this sample. The coefficients were estimated allowing for fixed and random effects for each industry. The Hausman test indicates for specification (1), that fixed effects estimated are valid while in the other three specifications the random effects is the suitable method. The coefficients on the yearly percentage change in the sales income, the share of operating profit out of income, and the mean of the firms age in each industry, are all significant and of the expected sign. Industry investment is a positive function of the profit and of the growth in activity in each industry and a negative function on the mean of the firm's age in the industry, since young firms invest more in order to grow rapidly. The coefficient on liquidity LIQ is positive but insignificant.The coefficient GOV_INV is also insignificant[12].

The impact of the expected variance of investment to income ratio (VAR_IY) is negative and significant in almost all regressions and for all methods of estimation: fixed and random effects. Note that this negative effect of uncertainty on investment ratio is significant even after controlling for liquidity constraints. In this respect the negative relationship between uncertainty and investment is not only due to the possibility that uncertainty is actually a proxy for credit constraints, since riskier firms are more likely to be credit constrained.

[12] The coefficient of the share of export in total income is also insignificant in contrast to Bar, Blass& Yosha (2001) finding in firm level regressions.

Table 3: Regression Results (Full Sample of panel A)

	Random Effects			
	(1)	(2)	(3)	(4)
VAR_IY	-0.02	- 0.02	- 0.019	-0.017
	(-2.30)	(-2.30)	(-2.2)	(-2.05)
DY (%)	0.10	0.10	0.092	0.09
	(3.12)	(3.09)	(2.99)	(2.91)
GOV_INV(%)		0.9	0.92	
		(1.04)	(1.1)	
PROF	0.003	0.003	0.004	0.004
	(1.96)	(2.22)	(2.64)	(2.577)
LIQ	0.005	0.002		
	(1.32)	(0.58)		
AGE	-0.002	-0.009	-0.018	-0.013
	(-0.96)	(-1.94)	(-1.96)	(-1.282)
R-SQ	0.453	0.414	0.317	0.337
Haus.	0.006	0.064	0.638	0.091

	Fixed Effects			
	(1)	(2)	(3)	(4)
VAR_IY	-0.014	-0.015	-0.015	-0.014
	(-1.97)	(-1.8)	(-1.83)	(-1.62)
DY (%)	0.073	0.08	0.078	0.074
	(2.307)	(2.43)	(2.48)	(2.357)
GOV_INV(%)		0.95	0.95	
		(1.24)	(1.24)	
PROF	0.004	0.004	0.004	0.004
	(2.575)	(2.55)	(2.849)	(2.861)
LIQ	0.003	0.001		
	(0.461)	(0.48)		
AGE	-0.042	-0.05	-0.04	-0.04
	(-2.591)	(-2.7)	(-2.81)	(-2.628)
R-SQ (within)	0.577	0.594	0.591	0.575

t statistic in parentheses. 8 industries, 48 observations, 215 firms, regressions include year dummies.

Note that the impact of the variance of investment to income ratio can be explained as a result of changes in the demand side rather change in the supply side. Furthermore this negative relationship estimated by the coefficient β_1 may be explained not only by the “nature” of shocks in each industry (whether all firms face shocks i.e. aggregate uncertainty or only part of them i.e. relative uncertainty), but by the strength and variance of the shocks in each industry. In this respect in panel B we try to overcome this two issues.

3.2.2 Results of the Second Panel (Panel B)

The dependent variable is the mean of equipment investment to output ratio across firms for each industry and for each period. The sample includes 2041 Israeli industrial firms in the 17 main industries (2 digit level) for the years 1990-1994. In order to capture only shocks and changes in the supply side (basically productivity shocks), we use as the main right hand variable the expectation about next period’s variance of the yearly change in the total factor productivity (TFP), across firms for each industry and for each period[13]. As explained earlier, differences in this expected variance (across firms) of yearly changes in TFP could be outcome of: (1) Differences in the “nature” of productivity shocks in each industry: whether the productivity shocks are common to all firms (aguc in our theoretical model), or only part of firms in the industry face productivity shocks (reuc in our model). (2) Differences in the strength and variance of the productivity shocks in each industry (θ in the model).

We use the following procedure in order to distinguish between these two effects: For each firm we compute the correlation coefficient (over the sample period), between the yearly change in its output to the yearly change in the industry output, which this firm belongs to. In order to avoid from missing data problems we include only the sample data of 1680 firms, which produce in <u>all</u> the sample years.

This correlation (ρ) is specific to each firm in the sample. We can now divide all firms in the sample to three groups according to the value of the correlation coefficient $(:\rho)$ (1) In this group we include all the firms (626 firms), that have a value of ρ which is above 0.75[14]. Those firms face a relative similar rate of change

[13] The change in TFP measured as Solow residual assuming a Cobb-Douglas function with constant return to scale to each firm in the sample. The coefficient of the production function were calculated by the annual proportions of the cost of input on the production cost (as in Eckstein and Regev (1999))

[14] We tried other values of threshold such as 0.5 and 0.6 and we get a similar results.

in their production like the rate of change in industry production. (2) Firms that have a value of ρ which is less 0.75 but above 0.25 (756 firms). (3) Firms that have value of ρ which is less 0.25 (298 firms). We can compute for each group and for each of the 17 main industries in each period all the relevant variables of the following estimated equation. Note that in this way the number of observations in the regression will be 153 (17 industries times 3 groups times 3 years). If there is substantial heterogeneity in output change across firms in the industry (reuc in our model) it would be captured by ρ that would be less than some threshold value (0.75 in our test). We define D1 as a dummy variable that gets the value 1 for all the group firms that have value of ρ which is above 0.75 else D1 gets the value 0. Note that we expect from the model, that D1 will affect investment positively. Using a panel for industries i=1….I , years t=1….T and groups j=1..J the estimated equation for panel B is of the form:

$$MIEY_{it}^{j} = \alpha_i + \beta_1 VAR\_DA_{i,t+1}^{j} + \beta_2 D1VAR\_DA_{i,t+1}^{j} + \beta_3 DY_{it}^{j} + \beta_4 GOV\_INV_{i,t-1}^{j}$$
$$\beta_5\ RENT_{it}^{j} + \beta_6\ AGE_{it}^{j} + \varepsilon_{it}^{j}$$

Where:

MIEY= mean of equipment investment to output ratio across firms[15].

VAR_DA= the expected variance of the yearly change in TFP across firms (with one year ahead).

D1VAR_DA= an interaction variable between the expected variance of the change in TFP to whether this industry is characterized by common shocks to all it's firms.

DY= the mean of the yearly change in the output firms ("acceleator" effects).

GOV_INV= the mean of the share of government subsidies out of investment in fixed assets (with one year lag, in percentage).

RENT= the mean of the share of capital rentals out of investment (in percentage).

AGE= the mean of the age firms in each industry and in each year.

[15] A similar regression for total investment ratio (structure and equipment) had insignificant results for β_1 and β_2.

The unbalanced panel B covers 51 industries (17 main industries times 3 groups) over the period 1990-1994 and 2041 Israeli industrial firms. Table 4 presents the results for these regressions. The coefficients were estimated by fixed and random effects for each industry. The Hausman test indicates for specifications (1) and (3) that random

Table 4: Regression Results (Full Sample of panel B)

	Random Effects			
	(1)	(2)	(3)	(4)
VAR_DA	- 0.020	-0.019	-0.019	-0.020
	(-1.99)	(-1.93)	(-1.92)	(-1.97)
D1VAR_DA	0.010	0.010	0.011	0.011
	(1.97)	(1.97)	(1.91)	(1.93)
DY	0.082	0.086	0.085	0.081
	(3.915)	(4.07)	(4.08)	(3.93)
INV_GOV(%)			-0.2	-0.2
			(-0.7)	(-0.7)
RENT (%)		-0.097	-0.104	
		(-1.29)	(-1.38)	
AGE	-0.057	-0.066	-0.06	-0.048
	(-2.33)	(-2.59)	(-2.13)	(-1.89)
R-SQ	0.397	0.405	0.405	0.398
Haus.	0.143	0.000	0.154	0.001
	Fixed Effects			
	(1)	(2)	(3)	(4)
VAR_DA	-0.023	-0.022	-0.019	-0.020
	(-1.63)	(-1.98)	(-1.98)	(-1.93)
D1VAR_DA	0.015	0.015	0.014	0.014
	(1.48)	(1.94)	(1.95)	(1.96)
DY	0.066	0.069	0.071	0.068
	(2.87)	(2.97)	(3.141)	(3.03)
INV_GOV(%)			-0.46	-0.4
			(-0.9)	(-0.9)
RENT (%)		-0.079	-0.08	
		(-1.1)	(-1.1)	
AGE	-0.030	-0.033	-0.033	-0.031
	(-2.59)	(-2.73)	(-2.85)	(-2.70)
R-SQ(within)	0.364	0.371	0.41	0.403

t statistic in parentheses. 17 industries, 3 groups,153 observation. All regressions include year dummies effects estimates are valid, while in other two specifications the fixed effect method is the more suitable one.

The coefficients on the yearly change in output, the means of the firms age in each industry are all significant for all of the specifications and of the expected sign. The coefficient RENT is negative as expected but it is insignificant. Note also that the coefficient of gov_inv is insignificant (as we get in regressions for panel A).

The impact of the expected variance of the yearly change in TFP on equipment investment ratio is negative and significant at 10 percent of level for almost all the regressions as expected from the theory[16]. The main finding is that, the net effect of the "nature" of the industry (whether the shocks in productivity are common to all firms in the industry so D1=1) on the investment ratio is positive (β_2>0)[17]. This last result supports our claim from the model, that aggregate investment is smaller in the relative uncertainty than in the aggregate uncertainty, since firms postpone more investment in the relative uncertainty.

It is worth noting that, if we add the dummy variable D1 without an interaction with other variables, the coefficient of this dummy variable is not significant, so all the effect of the "nature" of the shock on investment ratio, comes through the variance of the change in TFP. In this respect we also add to the regression, the interaction variable between D2 (get value 1 for all firms that have value of $\rho < 0.25$ else get value 0) to the expected variance of the change in TFP, but the coefficient of this interaction variable was not significant.

An alternative approach to investigate the effect of "nature" of the productivity shock on the uncertainty investment relationship is to estimate separately the same regression as pervious for two groups: (1) the group firms that have common shocks to productivity for each industry D1=1. (2) The rest of the firm that have value of D1=0 (reuc in our model). Table 5 presents the results for these two regressions using random and fixed effects methods. As expected we get a similar results to those in table 4, supporting our claim that, the negative impact of the expected variance of the

[16] These results remains even we use in the regression data, that include the overall 2041 firms.

[17]Alternatively we did the Chow –Fisher test for the stability of coefficient β_1 in all three groups and we got similar results.

yearly change in TFP on equipment investment ratio is higher and significant in the second group (represent relative uncertainty case) than in the first one (represent the aggregate uncertainty case).

Table 5: Regression Results by Groups (panel B)

	MIEY group firms with D1=1 "aggregate uncertainty"		MIEY group firms with D1=0 "relative uncertainty"	
	Fixed Effects	**Random Effects**	**Fixed Effects**	**Random Effects**
VAR_DA	- 0.014	-0.010	-0.022	-0.018
	(-1.17)	(-1.95)	(-1.218)	(-1.93)
DPROD	0.073	0.096	0.064	0.064
	(2.52)	(3.58)	(1.66)	(1.85)
INV_GOV(%)	-0.52	-0.14	-0.40	-0.24
	(-1.28)	(-0.78)	(-1.31)	(-1.03)
RENT (%)	-0.084	-0.107	-0.080	-0.094
	(-0.875)	(-1.11)	(-0.665)	(-0.759)
AGE	-0.04	-0.07	-0.02	-0.04
	(-2.71)	(-2.01)	(-0.97)	(-0.95)
R-SQ	0.394	0.387	0.447	0.448
Haus.		0.585		0.09
No Obs.	51	51	102	102

t statistic in parentheses.

All regressions include year dummies.

4 Concluding remarks

This paper uses a simple model of competitive equilibrium in order to describe the effect of different types of uncertainty on the delay of aggregate investment. Assuming investment is irreversible we can show in this theoretical framework that uncertainty over the future productivity of firms has a negative effect on aggregate investment. This negative effect exists even when only some of the firms in the industry face shocks to their productivity.

Furthermore, in order to find out which type of uncertainty leads to more delay of investment we have to examine the expected marginal profit of capital in both types of uncertainty. In this regard there are two effects: the price effect and the productivity effect, that determine the expected marginal profit of capital. The price effect increases the plausible range of the values of the parameters in which the expected marginal profit of capital will be lower under relative uncertainty than under aggregate uncertainty, while the second effect (productivity effect) operates in the opposite direction.

The answer to the question above therefore depends on these two effects as a result of three parameters: the strength of the productivity shock, the elasticity of demand and the capital share in production. Lower demand elasticity increases the importance of the price effect, and increases the plausible range of parameters in which, investment in the relative uncertainty will be lower, than in the aggregate uncertainty. In this respect decreasing the strength of the productivity shock or increasing the capital share decreases the importance of the "productivity effect", hence increases also the plausible range of parameters for which there is more delay of investment in the relative, than in the aggregate uncertainty.

Using a numeric solution it can be shown that, if we assume that the capital share is in the range of 0.2-0.4 (suitable to the capital share calculated for industry branches in the empirical section), we get that for any value of elasticity demand and for productivity shocks of less than 20 percent there is more delay of investment under relative uncertainty than under aggregate uncertainty. Note that productivity shocks in the model determine the annual rate of change of the total factor productivity (TFP), which in the empirical data less then 20 percent.

The main motivation to this result is that while in the case of aggregate uncertainty the firm is protect from the effect of competition within industry, this is not true for the uncertainty within industry (relative uncertainty). Hence, for a given level of uncertainty, the effect within industry exceeds the effect between industries.

This study presents two different sets of panel data of firms in the Israeli manufacturing industries in 1990s: Panel A contains information from the annual accounts of 215 Israeli industrial firms that were traded in the Tel-Aviv stock exchange for the years 1990-97. Panel B contains information on 2230 Israeli industrial firms (plants), with five or more employees for the years 1990-94.

The empirical evidence based on panel data regressions shows a negative relationship between aggregate investment and uncertainty, even after controlling for liquidity constraints. In this respect the negative relationship between uncertainty and investment is not only due to the possibility that uncertainty is actually a proxy for credit constraints, since riskier firms are more likely to be credit constrained.

The empirical result from the second panel-data (panel B) regressions supports also our main finding from the model, that aggregate investment is smaller in the relative uncertainty than in the aggregate uncertainty, since firms are more likely to postpone investment in the relative uncertainty.

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Appendix

TABLE 6
Capital share and change of totol factor productivity (TFP) by industry (panel B)

(yearly averge 1991-1994, percent)

Industry	Capital share*	change in TFP
Mining and quarring	29	4.2
Foodand beverage	33	0.3
Textiles	28	2.5
Clothing &made up textiles	28	2.6
Leather and its products	18	4.8
Wood and its products	22	5.4
Paper and its products	28	1.4
Printing and publishing	22	-2.7
Rubber and plastic prouducts	32	5.5
Chemical and oil products	33	5.8
Non metahlic muneral products	21	1.9
Basic metal	23	2.3
Metal products	20	3.2
Machinery	30	3.6
Electrical equipment	22	1.6
Transport equipment	15	-1.1
Miscellaneous	24	1.9
Average	25	2.5

* The change in TFP measured as Solow residual assuming a Cobb-Douglas function with constant return to scale to each firm in the sample.
The coefficient of the production function were calculated by the annual proportions of the cost of input on the production cost (as in Eckstein and Regev (1999))