The effect of business risk on manufacturing investment
Sectoral survey evidence from Ireland

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Received 11 January 1999; received in revised form 30 August 1999; accepted 31 August 1999

Abstract

This paper analyses the results of a special sample survey on risk and investment carried out using the European Union investment survey sampling frame for Ireland. The paper looks at decision-making by large manufacturing firms located in Ireland to see whether their investment decisions can be understood within the various models of risk that economists use. Equilibrium and disequilibrium models are examined to see what best explains the behaviour revealed by the firms’ responses. The paper develops a categorisation of the main theoretical channels of influence from risk to investment. In the light of this theory, the survey replies of Irish firms are used to assess the importance of the different channels of influence. © 2001 Elsevier Science B.V. All rights reserved.

JEL classification: L6 E22

Keywords: Manufacturing; Investment; Business risk; Ireland; Real options

1. Introduction

There is a measure of consensus that risk is a missing variable in explaining the relatively volatile behaviour of investment (Driver and Moreton, 1991; Pindyck and Solimano, 1993; Price, 1995). But theoretical work has proceeded faster than empirical observation. There

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are a great number of plausible models but we simply do not know which transmission mechanism from risk to investment is most important.

This knowledge gap must cause problems for policymakers on two fronts. Those charged with promoting investment will not know where specific market failures might lie. Those charged with reducing risk, e.g. by promoting macroeconomic stability will have difficulty in knowing the economic variables that are most important to stabilise from the perspective of encouraging investment.

Surprisingly little is known about the mechanisms by which risk of various sorts affect the investment decisions of firms. This contrasts with the numerous theoretical models, both of the capital stock under risk (Nickell, 1978; Aiginger, 1987; Driver and Moreton, 1992) and the timing of investment behaviour (Dixit and Pindyck, 1994). To put it crudely we have little idea whether the main mechanism is risk attitude (e.g. aversion), or the effect of irreversibility, or non-linearities operating via Jensen’s inequality. Neither do we know whether the main problem for firms is one of input cost risk or demand risk, though the respective models may yield different results.

Our ignorance is compounded by the lack of any real knowledge of the ex-post controls that firms tend to employ in response to disequilibrium between actual and desired capacity. For example, in the event of a downward demand shock with irreversible excess capacity, do firms tend adjust price or capacity utilisation or both? Faced with a similar upward shock and long lead times do firms tend to raise price, to lengthen order books or to subcontract?

In this paper we first categorise some major models in the literature of capital investment under risk. In Section 3, we use the results of a survey of large Irish manufacturing firms to assess the relevance of these theories. Section 4 concludes.

2. Categorising theories of capital investment under risk

Economic theory offers a bewildering variety of ways in which investment can be affected by risk (Aiginger, 1987; Driver and Moreton, 1992; Abel et al., 1996). Not only are several possible transmission mechanisms but the strength and even the sign of these effects are heavily influenced by variation in the functional form of standard economic relationships. Here we make some observations about the most important effects of risk.

2.1. Non-linearities

If marginal profit is linear in the stochastic variable, risk will not bias the input decision. Non-linearities in the marginal profit function arise due to specific forms of demand or production functions. In general the influence of risk on investment is ambiguous. The literature has tended to focus on the case of price-taking firms with substitutability between factors. In this case we expect investment to be biased towards the fixed factor by both demand and input cost risk. We refer to this as the convexity mechanism. For monopoly or imperfect competition the convexity effect is weakened and the direction of bias may be reversed under demand risk (Pindyck, 1991).
2.2. Rationing disequilibrium

Rationing models concern a disequilibrium where sales are determined by the minimum of production and demand. One standard model, derived from inventory theory, is the “newsboy model” which can be adapted to explain the (irreversible) decision to hold fixed capital under risk. The disequilibrium literature generally assumes a downward bias to investment. However, if profitability is above some critical level the theory implies excess planned capacity to guard against lost sales. In the simplest of these models with fixed costs only and with symmetric demand the critical price–cost (profitability) ratio is 2 (Nickell, 1978, p. 72; Aiginger, 1987, p. 69). If price does not exceed twice the fixed cost, the seller will plan to hold insufficient capacity to meet expected demand because the penalty for holding an unused unit \( c \) will more than outweigh the gain of a marginal sale \( p - c \).¹

2.3. Risk attitude

Under risk aversion it is possible to derive general results about the direction of bias of capital input if the marginal profit function is linear in the stochastic variable. One important implication of risk aversion is that the decision variable will be lower than under risk neutrality if it is positively related under certainty with the stochastic variable. For example with positive dependence between prices and capacity under certainty, an extra unit of capacity implies higher profits; under risk aversion uncertain extra profits are valued less than under certainty, thus reducing optimal capacity. However for input cost uncertainty, with capacity as the decision variable, the dependence between cost and capacity under certainty is negative and the direction of bias may be reversed, i.e. the firm may install more capacity under risk if it is risk-averse (Aiginger, 1987, pp. 35, 45; Nickell, 1978, p. 81).²

2.4. Dynamics and irreversibility

The theory of investment under risk has been enhanced by models of the dynamic effects of uncertainty. The basic idea is that firms possess valuable opportunities (real options) which can be exploited with some discretion as to time but which once exercised are at least partially irreversible. The exercise of the option (investment) thus implies a cost which should be added to the usual user cost of capital when deciding on the timing of investment. Waiting makes costly (irreversible) mistakes less likely and this can explain lagged adjustment (Dixit and Pindyck, 1994).

Real option theory does not, however, yield unambiguous predictions about the direction of bias caused by risk. If irreversibility is strong, if information is acquired by waiting, and if the cost of waiting is low, then demand risk should delay investment. However, immediate investment may be justified if options are not firm-specific (there is strategic competition) and if ex-post controls for capacity shortage are lacking so that an inability to expand entails unavoidable losses.

¹ For more complex models including two-factor models and models with price flexibility, see Lambert and Mulkay, 1990; Driver et al., 1993, 1996).
² Where substitution between factors is possible ex-post, the latter effect is reduced in importance (Nickell, 1978).
3. An assessment of the theories using survey replies

We now add empirical substance to the theoretical propositions by reporting a set of survey results. Survey evidence is not always given serious attention as researchers tend to worry about incentives for respondents to reply truthfully. Some recent work has shown how survey evidence on expectations are internally consistent (Dominitz and Manski, 1997; Dominitz, 1998). The accuracy of the European Union Investment Survey, of which the current survey is a part, has been examined statistically and the results have confirmed a close correspondence between expectations and outcomes (European Commission DG2, 1997).

The sampling frame used for this Survey is the standard set of large manufacturing firms regularly contacted for the half-yearly investment survey carried out by the Irish Economic and Social Research Institute (ESRI) as part of the EU investment survey. A set of extra questions was included with the October 1995 survey form; these were designed by the authors as part of a study on private sector capital investment in Ireland, commissioned by the Irish National Economic and Social Council. The number of usable replies was 228.3

The sample is disaggregated using sectors defined by the ESRI. The **Traditional** sector includes such industries as clothing, ceramics, building materials, and the drinks industry. The **Food** sector covers mainly processed foodstuffs. Finally, the **Hi-Tech** sector, a major recipient of foreign direct investment, comprises electronics and specialised chemicals.

3.1. Ambiguity in direction of bias

The role of non-linearities in biasing capital input dominated the economics of investment under risk until attention turned more recently to the issue of irreversibility. According to this theory the direction of bias to capital input is ambiguous as discussed in Section 2.1. However, there is little evidence from the survey results that the direction of bias to investment under risk is ambiguous. The Survey sought to establish whether different types of risk inhibited investment. The box below shows the question on the effect of risk (Question A) along with the weighted percentage responses.

<table>
<thead>
<tr>
<th>Q. A</th>
<th>Do the following types of uncertainty tend to seriously inhibit your investment commitments:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>uncertainty about future demand or price</td>
</tr>
<tr>
<td>YES</td>
<td>SOMewhat 37</td>
</tr>
<tr>
<td>uncertainty about future unit input cost</td>
<td></td>
</tr>
<tr>
<td>YES</td>
<td>SOMewhat 64</td>
</tr>
<tr>
<td>other uncertainty</td>
<td></td>
</tr>
<tr>
<td>YES</td>
<td>SOMewhat 55</td>
</tr>
</tbody>
</table>

The message from these responses is clear. Capital investment is severely inhibited by demand/price risk and somewhat inhibited by other forms of risk, especially input-cost risk.4 The fact that virtually all of the sample thought price/demand risk to inhibit investment to some extent might be thought strong evidence against the importance of the

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3 Unless otherwise stated, the responses are not given as the percentage of all firms, as that would give undue prominence to smaller enterprises. Rather the replies are weighted to reflect the amount of investment in 1995.

4 Other risks prompted include exposure to debt and installation cost risk. There is some variation in replies across the industrial sectors, with the Food sector chiefly inhibited by input cost uncertainty.
The rationing approach of Section 2.2 suggests that investment will be inhibited if the cost of a foregone sale due to a capital constraint is low in relation to the unit cost of capacity. A firm has to weigh the expected damage to profits from excess capacity against the damage from deficient capacity, i.e. it has to balance the costs of carrying unused capacity against the cost of stock-outs. In principle it is possible to measure this directly using the profitability indicator \( p/c \) in Section 2.2 to measure the shadow price of capital. This indicator is, however, theoretically correct only where the value of relaxing the capital constraint by one unit is given by the output price \( p \). In practice the true value may be more or less than this depending on such factors as loss of goodwill and the slope of the marginal cost curve at full capacity. In the Survey we take the account of these objections by obtaining a subjective measure of the cost of too little or too much capacity. Question B records the exact question along with weighted percentage replies.

The results show that nearly half find “capacity shortage” more damaging and a quarter find “excess capacity” more damaging. On the face of it this might appear to indicate that the disequilibrium argument of Section 2.2 cannot account for the preponderance of investment inhibition due to risk reported earlier. Certainly if the demand distribution were symmetrical about normal capacity, the results would appear to indicate that only a minority of firms would invest less in the presence of risk than under certainty due to this channel of influence.

Further insight may be gained by studying the mechanisms by which capacity errors impact on profits. We use here two supplementary questions in the Survey that looked at what firms did when they had too much or too little capacity (ex-post controls). The questions are given below along with the weighted percentage replies:
Table 1
Characteristics of the group “excess capacity most damage” and the group “capacity shortage most damage”

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>“Excess capacity most damaging” (Question B, 1st response)</th>
<th>“Capacity shortage most damaging” (Question B, 2nd response)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage of price cutter (Question C, 2nd response)</td>
<td>75</td>
<td>13</td>
</tr>
<tr>
<td>Percentage of price taker (Question C, 3rd response)</td>
<td>9</td>
<td>59</td>
</tr>
<tr>
<td>Percentage of lengthen order books (Question D, 1st response)</td>
<td>66</td>
<td>25</td>
</tr>
<tr>
<td>Percentage of subcontract, etc. (Question D, 2nd response)</td>
<td>33</td>
<td>73</td>
</tr>
<tr>
<td>Percentage of inhibited by demand/price (Question A, 1st response)</td>
<td>70</td>
<td>40</td>
</tr>
</tbody>
</table>

The percentages in the table refer to the weighted percentage response of firms conditional on the response to Question B as indicated in the column headings.

The responses to Survey Question C indicate that only two out of five firms are price takers. In the event of surplus capacity, price-cutting seems a quite common ex-post control. By contrast, in the event of insufficient capacity there is virtually no recourse to price rises at firm level. Rather, subcontracting or extra shift-work are most common. Longer order books (customer rationing) scores a minority response, implying that for many firms it is either more profitable to supply at premium cost or they are contracted to supply. These replies suggest that the reason why capacity shortage is seen as more of a problem than excess capacity has to do with the costs of subcontracting or extra shift-work at full capacity.

We now cross-tabulate some of the ex-post responses with the percentages indicating that excess capacity or capacity shortage were most damaging. The results are shown in Table 1.

In the event of a downward demand shock the “excess most damaging” group tends to lower price to try to maintain capacity utilisation. This group also tends to rely on lengthening order books in the event of excess demand, presumably because this is a cheaper option to supplying at a penalty cost. The worry over excess capacity and the susceptibility to price cuts explains why this group is heavily concerned with demand/price risk.

The “shortage most damaging” group is quite different. These firms tend to be price takers. They tend to subcontract if short of capacity, possibly because monopsonistic buyers expect reliable supply. Because of these characteristics they are not quite as concerned about demand risk as the “excess most damaging” group. Indeed, it is theoretically possible that risk would encourage some of these firms to invest more than under certainty due to the convexity result discussed earlier.

It is also of interest to show some characteristics, disaggregated by sector, as in Table 2. The major contrast is between the Food sector and others; the ratio of those citing damage from capacity shortage to those citing damage from excess capacity is higher for this sector by a factor of 3 or 4. The great majority of the Food sector are price takers, many of whom will be supplying to contract. This characteristic, along with a lower incidence of lumpy capital (see Section 3.4) can explain the emphasis of the Food firms on the damage from capacity shortage.
Table 2
Survey response on ex-post controls by sector (percentage with characteristic within each sector)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Hi-tech</th>
<th>Traditional</th>
<th>Food</th>
</tr>
</thead>
<tbody>
<tr>
<td>Price taker (Question C, 3rd response)</td>
<td>34</td>
<td>32</td>
<td>73</td>
</tr>
<tr>
<td>Excess capacity most damage (Question B, 1st response)</td>
<td>27</td>
<td>27</td>
<td>11</td>
</tr>
<tr>
<td>Capacity shortage most damage (Question B, 2nd response)</td>
<td>45</td>
<td>36</td>
<td>60</td>
</tr>
</tbody>
</table>

3.3. Risk attitude

As discussed in Section 2.3 firms that are averse to demand risk may invest less than others who are risk-loving or risk-neutral. Put differently, risk-averse firms will only undertake risky projects if the return compensates for their aversion to risk. In the Survey we established the risk attitude of firms by asking the question:

Q.E Suppose you compare two projects. The return for project A is reasonably certain. Project B has a higher payback but also considerable risks. Which is most true:
   - We tend to prefer the project with the known but lower rate of return 71
   - We tend to prefer the project with the higher return, but also higher risks 18
   - We calculate the statistical "average" rate of return and choose on this basis 11

Clearly Irish firms are extremely risk-averse. The responses may be contrasted with the responses to a similar survey question asked of Austrian firms (Aiginger, 1987). The type of firm seems similar with most of the Austrian firms having domestic market shares between 5 and 50 percent. For medium-size projects costing half their annual investment programme, risk behaviour was spread fairly evenly for the Austrian firms between risk-neutrals, risk-lovers and risk-aversers. For projects many times the annual budget, just over 50 percent were risk-averse with 12 percent risk-lovers. These figures show a pronounced contrast with firms operating in Ireland. Irish firms are far more risk-averse than those in Austria. A typical project for Irish firms is regarded with far more risk aversion than a very large project is in Austria. This information suggests that risk aversion is a powerful channel of influence in biasing down investment.

3.4. Effects of investment delay

Risk affects not only the scale of an investment project but also the timing of it. The Survey attempted to discover whether firms delayed commitment because of risk or whether firms invested promptly. These options do not, however, exhaust the possibilities since some firms will need to delay for technical reasons while other will not need to invest if they are carrying excess capacity. The survey also examined the effect of delaying a capital investment.

The questions are shown below along with the weighted percentage replies:
Table 3
Survey response on investment timing by sector (percentage with characteristic within each sector)

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Hi-tech</th>
<th>Traditional</th>
<th>Food</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delay-risk (Question F, 1st response)</td>
<td>33</td>
<td>26</td>
<td>14</td>
</tr>
<tr>
<td>Delay-lumpy capital (Question F 2nd response)</td>
<td>27</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>Start investing immediately (Question F, 3rd response)</td>
<td>36</td>
<td>50</td>
<td>27</td>
</tr>
<tr>
<td>Carry excess capacity (Question F, 4th response)</td>
<td>4</td>
<td>17</td>
<td>51</td>
</tr>
<tr>
<td>Drastic/substantial effect (Question G, 1st or 2nd response)</td>
<td>74</td>
<td>48</td>
<td>34</td>
</tr>
</tbody>
</table>

There is some evidence here that risk delays investment and that delay also damages firms’ prospects. However, the spread of replies, especially to Question F indicates how hard it is to capture investment behaviour by a single model. The disaggregated results also show quite a lot of variation between the sectors, both in the attitude to timing and in the perceived damage from delay, as shown in Table 3.

Table 3 shows a contrast between the Hi-tech sector and the rest. The former has a much higher incidence of delay due to lumpy capital which probably indicates that the investment decision is more irreversible and less incremental than in the other sectors. The combined responses of *invest immediately* or *carry spare capacity* scores only 40 percent for the Hi-tech sector as compared to figures of about 70 or 80 percent for the other sectors. This suggests a more cautious approach by the Hi-tech sector. This is underscored by comparing the ratio of the *immediate investment* response to that of *delay due to risk*. We observe that the Hi-tech ratio of about unity is only half that of the other sectors.

To some extent these results confirm that risk plays a role in delaying investment as in the real options approach (Dixit and Pindyck, 1994). But simple real option models which take no account of the cost of delay are unlikely to capture the complexity of the investment decision. As shown in Table 3, the Hi-tech sector gives the strongest response that delayed investment causes damage to profits.¹ Thus, real options decisions involve

¹ In a logit regression of the “little damage” category on the responses to Question F, there is a significant negative coefficient for the lumpy capital response. Thus firms with the biggest incentive to delay may also face the biggest threat from delay.
a balance between the benefits of delay on the one hand and the benefits of acquiring an option to expand production on the other (Abel et al., 1996).

4. Conclusions

The Survey responses have been useful in illustrating the channels of influence from risk to investment. We have discovered no strong effect of risk due to convexities, though where price-taking behaviour dominated, as in the Food sector, there seemed a weaker negative effect on investment from demand or price uncertainty.

The effect of anticipated disequilibrium involving excess capacity or capacity shortage was investigated by asking which of these two outcomes would imply greater damage to firms. The survey found that capacity shortage was perceived as the greatest threat. It appears that there are two distinct groups characterised by a fear of either under-capacity or over-capacity. For those who fear excess capacity the response to over-capacity is to cut price. Capacity shortage is simply met by lengthening order books. For those concerned with capacity shortage, the majority are price takers; these firms will lose out if demand exceeds capacity as they then have to subcontract or incur penalty costs. On the face of it the results here constitute something of a puzzle. Why are firms constrained in their investment by risk if the greatest threat is capacity shortage? One answer may be risk aversion.

The effect of risk-aversion was ubiquitous for the survey firms with little evidence of risk-loving or even risk-neutral behaviour. In equilibrium models, risk aversion will tend to bias down capital input under demand/price risk, which is the most important type of risk for most of the sample. Risk aversion in disequilibrium models will strengthen any bias already present. We have already noted that the disequilibrium effect recorded in the survey could cause an upward investment bias for those firms worried about capital shortage. In practice however, firms may not invest more than under certainty because the effect is blunted by risk aversion.

The theory of investment dynamics under uncertainty predicts that firms may delay if irreversibility poses a more serious threat than costly expansion ex-post. The survey showed that risk did affect the timing of investment for between a quarter and a third of the sample. The greatest caution in respect of timing was in the Hi-tech sector which was also the sector with the greatest damage from delay. Problems of irreversibility (which favours delay) and expandability (which favours prompt investment) seem to coexist in the same sector suggesting that there is no clear effect of risk on timing likely to emerge from investment studies unless firm-level effects are carefully modelled.

References


