INVESTMENT BEHAVIOUR UNDER UNCERTAINTY:
AN ECONOMETRIC ANALYSIS OF SWEDISH PANEL DATA

Christos Milopoulos
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1993
To my parents
Elpiniki and Spyros
Abstract

This thesis is an empirical investigation into the investment behaviour of Swedish manufacturing firms. In the core of the investigation lies a stochastic optimisation problem which postulates that the firm aims at minimising its total production costs given non-static expectations of the demand for its output and of the prices of the production inputs. The solution to this optimisation problem gives an investment decision rule. Upon the substitution of the firm's expectations formation mechanism into that rule, a closed-form investment demand function is obtained. The investment function is subsequently modified (augmented) in two respects. First, the perfect capital market hypothesis underlying the optimisation problem is relaxed, and the firm's financial condition, as captured by its cash flow, is allowed to affect its investment spending. Second, it is argued that boundedly rational agents (a maintained hypothesis) commit expectations errors which affect capital spending in two ways. On the one hand, the firm revises partially its investment plans in the light of currently revealed unfulfilled expectations. On the other hand, unused capacity, which is the result of past uncorrected expectations errors, have an effect on investment decision.

Contrary to the tradition in the literature, the specification of the firm's expectations formation mechanism is empirically determined rather than imposed in an ad hoc fashion. Moreover, the information set utilised by the firm is augmented and allowed to contain variables in addition to the expectational variable's own past history.

The empirical implementations in this study were carried out on panel data on major Swedish firms. A new econometric methodology was used which proposes the estimation and testing of models on panel data by drawing upon the analogy with the general simultaneous equations system.

The empirical implementation of the firm's expectations formation mechanisms showed that the discrimination among some of the most frequently used specifications of these mechanisms, such as the partial adjustment and error-correction specification, can be rather difficult on empirical grounds. On the other hand, the empirical analysis indicated that the firm's formation of expectations is based on augmented information sets.

This result was also obtained from the empirical implementation of the investment demand function. In addition, the firm's expectations were found to be non-static. With respect to the determinants of investment, evidence was found in support for a significant
output-accelerator effect on Swedish firms' capital spending. Significant was also the effect of the cost of capital and the cost of labour. Contrary to what it was expected, the financial condition of the firms was found to have no effect on their investment expenditures. On the other hand, unused capacity turned out to have a notable effect on capital spending, whereas currently revealed unfulfilled expectations, although significant, turned out to have a relatively weak effect.
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Preface

The beneficial effects of fixed capital spending on a society's welfare have been the driving force behind my interest in firms' investment behaviour. Apart from constituting a significant source of demand for the products of construction and producers' durable goods industries, the firms' fixed investment provides for the future growth of employment and living standards by renewing and expanding the stock of productive capital assets. My hope is that with this thesis I have contributed to an improvement and an enhancement of our understanding of the mechanisms that lie behind the firms' investment decision-making.

The decision to give an empirical orientation to this thesis stems from my interest in the application of econometric methods for empirical implementations of economic theory in general and firms' investment behaviour in particular. A common econometric methodology underlies all the empirical applications contained in the thesis. It is my hope that the presumptive reader will find this methodology interesting and will appreciate my endeavours to apply it in a correct and appropriate way.

In the course of writing this thesis, I have benefited considerably from comments, support, and encouragement from many people whose kind help I wish to acknowledge here.

My greatest debt is to my thesis adviser, Professor Anders Klevmarken, who encouraged and supported my work from its very beginning to this thesis. Without his insightful comments and constructive advice which provided necessary help in solving my seemingly insurmountable problems and avoiding possible pitfalls, this thesis may have remained unfinished. It is my hope that my work reflects his influence, although I would not want to implicate him in any possible remaining weaknesses.

I owe many thanks to Dr. Bo Walfridson for all the time and effort he has given to help me detect inconsistencies and improve the final version of this thesis. His knowledgeable comments and suggestions have been of invaluable importance to me.

I have also benefited substantially from discussions with Dr. Boo Sjöö. His knowledge and insight into dynamic econometric models was of great importance for the analysis in Chapter 5.
My gratitude also goes to Gunnar Eliasson, Director of The Industrial Institute for Economic and Social Research, IUI, Stockholm, who kindly allowed me access to the Institute’s survey data. Without these data it would be impossible to produce this work. I must also mention the inspiring and valuable discussions with Gunnar Eliasson at the IUI in the early stages of my thesis.

In the course of my work I have benefited considerably from the Econometrics Workshop held at the Department of Economics, Gothenburg University, during the past year. I would like to thank the participants for their contributions to the discussions and their comments on earlier drafts of my thesis. In particular, my thanks go to Dr. Lennart Flood, Dr. Ali Tasiran, Almas Heshmati, Anders Johansson, Max Zamanian, Håkan Locking, Ahmet Yaprak, Peter Brose, Lulseged Yohannes, Lars Bager-Sjögren and Samboja Hatibu Haji. My special thanks go to Anders Johansson for the time he has given to read parts of Chapter 5 and for pointing out errors I had overlooked.

Professors Arne Bigsten and Lennart Hjalmarsson have read earlier versions of my thesis and provided constructive advice, valuable help and encouragement. I thank them both.

My thanks also go to Karen Lindberg who helped me to proofread my thesis, to Eva Jonason, Eva-Lena Neth-Johansson, Jeanette Börjesson, Ulla Mellgren and to the rest of my colleagues at the Department of Economics who contributed to a pleasant and inspiring atmosphere.

I would like to gratefully acknowledge the generous financial support of the Swedish Institute, Stockholm, during my very first years as a guest student at the Department of Economics. My gratitude also goes to the Faculty of Social Sciences, Gothenburg, Adlerbertska Foundation, Gothenburg, and Funds of Gothenburg School of Economics and Commercial Law, Gothenburg, which provided the necessary funds for my research. Finally, I am specially grateful to the Department of Economics, Gothenburg, and the University of Gothenburg for allowing me access to their facilities over the last years.

Many special thanks go to my colleagues and close friends Almas Heshmati and Zheng Jinghai. With them I shared not only an office but also, and most importantly, my frustrations, inspirations, troubles, and ambitions during some of, the until now, most significant years of my life. Thank you for being there.
Finally, I am deeply grateful to my parents and to the rest of my family for the great deal of understanding, encouragement and support that they gave to me during all these years. This thesis is dedicated to them.

Gothenburg, April 1993

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List of Variables

\[ W = \text{Labour cost per hour including employers' contribution to social security.} \]

\[ \text{W}^* = \text{Expected labour cost per hour including employers' contribution to social security.} \]

\[ Q = \text{Production volume.} \]

\[ Q^* = \text{Planned production volume.} \]

\[ I = \text{Sum of real net investment in machines and construction.} \]

\[ \text{IREV} = \text{Investment revision.} \]

\[ K = \text{Real total fixed capital stock.} \]

\[ \text{CU} = \text{Capacity utilisation in percent of full capacity.} \]

\[ \text{VA}_H = \text{Value added per hour.} \]

\[ L = \text{Actual employment level.} \]

\[ \text{UNVAC} = \text{Unfilled vacancies.} \]

\[ \text{CF} = \text{Cash flow.} \]

\[ \text{PM} = \text{Intermediate goods price index.} \]

\[ \text{PL} = \text{Labour cost index including employers' contribution to social security.} \]

\[ \text{PL}^* = \text{Index for expected labour costs.} \]

\[ \text{PI} = \text{Weighted average of investment goods price index for machines and construction.} \]

\[ \text{P} = \text{Output price index.} \]

\[ \text{P}^* = \text{Index for expected output price.} \]

\[ w = \text{PL}/\text{PM}. \]
\[ \omega^* = P_L^0 / PM. \]

\[ p = P/PM. \]

\[ \rho^* = P^* / PM. \]

\[ q = L^0 / PM. \]

\[ r = \text{Nominal long-term interest rate defined as yields to maturity of long-term Swedish government bonds.} \]

\[ \delta = \text{Weighted average of depreciation rates of machines and constructions.} \]

\[ \pi = \text{Percentage change of Swedish Consumer Price Index from previous year.} \]

\[ \bar{\omega} = q(r - \pi + 0.04 + \delta) \text{ where 0.04 is an arbitrary risk premium.} \]
Chapter 1

Introduction

Few topics have dominated theoretical and empirical research in economics during the last decades as much as the firm's fixed investment behaviour. An understanding of the factors that determine investment spending is a prerequisite for a satisfactory explanation of its variation over time and for any policy recommendation to have merit. Yet, there seem to be few fields in economics where the lack of consensus among theorists and practitioners on the modelling of economic behaviour is so profound as in the field of firm's investment behaviour. Unfortunately, resorting to empirical evidence has not resolved the controversies and in some cases it has increased the confusion rather than the understanding of the determinants of investment expenditures.

Modern studies on firms' investment behaviour can be classified in two major categories. The first category comprises studies that are based on results provided by Jorgenson (1963) in his seminal paper on neoclassical capital theory and investment behaviour. Jorgenson's investment demand model is the classic flexible accelerator model which predicts that actual net investment is a distributed lag on past changes in the desired capital stock. Desired capital stock in turn is determined either by factor prices or output and the user cost of capital. The flexible accelerator model stems from the solution of an inter-temporal optimisation problem which postulates that the firm aims at maximising its net worth over the planning horizon, subject to technological and capital accumulation constraints.

The flexible accelerator model based on the optimisation problem as originally formulated by Jorgenson was not fully internally consistent: the optimisation problem was only able to yield a desired level of the capital stock while leaving unclear how this relates to its optimal time rate of change. Jorgenson solves the problem by appending, in an ad hoc fashion, a distributed lag structure in order to obtain an implementable flexible accelerator model. A theoretical rationalisation of the latter was however subsequently provided by Eisner and Strotz (1963) and Lucas (1967) by means of the increasing costs
of adjustment hypothesis. This hypothesis postulates that due to frictions and lags the firm is prevented from immediately adjusting the existing level of capital stock to its desired level, while a rapid adjustment can only occur at increasing costs. When the costs of adjustment hypothesis is taken into account during the optimisation, the flexible accelerator model is obtained.

An investment demand function of the flexible accelerator type can also be derived from an interrelated factor demand model originally developed by Nadiri and Rosen (1969). This model postulates that the firm chooses the optimal level of capital stock simultaneously with the levels of the rest of the production factors. The underlying optimisation problem assumes that the firm aims at minimising the present value of its total cost and incurs increasing costs of adjusting the level of its quasi-fixed factors. The solution of the optimisation problem yields the desired level of the capital stock as a function of output, the cost of capital and the cost of employing the rest of the production factors such as labour, energy, intermediate goods, etc.

The second category of investment models are those based on Tobin’s $Q$ model. Originally developed along the financial side of investment, it was subsequently shown that the $Q$ approach can also be viewed from the production side (Abel (1980)). In this case, the same kind of optimisation problem including adjustment costs that produces the flexible accelerator model also yields a relationship where investment depends on marginal $Q$. Marginal $Q$ is defined as the ratio of the market value of an additional unit of capital to its replacement cost. As the market value is just the expected future returns from the piece of capital, the firm can increase its market value by investing when $Q$ exceeds unity.

In deriving the aforementioned investment models, the assumption of perfect factor and capital markets is usually made. Hence, the prices of the production factors and the cost of capital (along with the output level) are the only variables that determine the desired level of capital stock since in perfect markets, prices embody all the relevant information. The assumption of perfect capital markets is probably the one that has been most frequently questioned. On the presumption that all firms do not have equal access to capital markets or do not have access to capital at the price set in these markets, the standard cost of capital variable is not the only relevant variable when it comes to the financing of the firms’ capital formation. The availability of internal finance in the form of, e.g. retained earnings or cash flow, may also affect investment expenditure as it provides not only necessary funds but also at a lower cost compared to external financing. Hence, a firm’s investment decision should not be independent of its financial condition. The dependence of the two was
recognised by Meyer and Kuh already in the late 1950s (Meyer and Kuh (1957)). The subsequent dominance of Jorgenson’s neoclassical capital theory, however, contributed to the separation of the firm’s real investment decisions from its financial condition. The theoretical basis for this separation was provided by Modigliani and Miller (1958) which demonstrated that in perfect capital markets the firm’s financial structure and financial policy is irrelevant to its real investment. Current investment models, however, based either on the flexible accelerator or the $Q$ ratio often assume the dependence of the latter on the former by introducing variables in the investment model that capture this dependence. Among the most popular ones are some specification of the firm’s profit (Catinat et al. (1987)) and the cash flow variable (Fazzari, Hubbard and Petersen (1988)).

Neoclassical investment models do not allow for any effect of the level of capacity utilisation on the firm’s investment spending. This is consistent with the assumption underlying the optimisation problem that the firm is always on its production function. Nevertheless, observed slacks in capacity utilisation should affect investment demand. If more capital is necessary either in order to expand output or because of a change in relative input prices, the firm can simply utilise its free capacity without increasing net investment. The rate of capacity utilisation has therefore been used as an argument in the investment model (Bean (1981), Bergström (1986)).

An issue that has been extensively discussed in the literature on firms’ investment behaviour pertains to the role of expectations in firms’ investment decision-making. As mentioned earlier, Eisner and Strotz, and Lucas provided the theoretical rationalisation of the flexible accelerator model by means of the costs of adjustment hypothesis. As it was subsequently shown by Gould (1968), however, the flexible accelerator model implicitly assumes that the firms’ expectations as to the variables that determine the desired level of capital are static. Under the more realistic assumption of nonstatic expectations, the optimal level of capital depends on the entire future course of the exogenous variables. Hence, observed investment is the result of firms’ perceptions as to this course, and the problem that now arises is what these perceptions are. The $Q$ model has the advantage that one does not need to be concerned about expectations as these are summarised in the $Q$ ratio itself. That is, the market’s judgement of the future stream of net earnings ought to be reflected in the market value of the firm. Thus, to the extent the market is correct in its assessments, there is no need to measure expectations directly. On the contrary, in investment models of the flexible accelerator type one needs to know the firms’ expectations of the exogenous variables for the entire future. As these expectations are typically unobservable the practice in the literature has been to assume that expectations
are generated by an expectations formation mechanism the functional form of which is chosen by the analyst on some theoretical grounds (Hansen and Sargent (1981), Sargent (1981), Prucha and Nadiri (1986), Morisson (1986)). The scope of the expectations formation mechanism is typically kept limited as the formation of expectations is solely based on information from the past history of the variable(s) as to which expectations are formed, while the likely independent effect of some additional exogenous variables on expectations is ignored\(^1\).

As mentioned earlier, there is a considerable lack of consensus among theorists and practitioners on the modelling of investment behaviour, the break running between the flexible accelerator approach and the Q approach. Resorting to empirical evidence has not offered any clear indication in favour of either approach as empirical implementation of the two often gives unsatisfactory results. According to standard neoclassical investment theory, output is determined by the firm's choice of capital stock and hence is an endogenous variable. Capital stock in turn is primarily driven by relative factor prices. Therefore, if the neoclassical model is correct one would expect firms to use prices and not quantities as signals in making their investment decisions. The results typically obtained from empirical implementations of the neoclassical investment model, however, indicate that investment responds strongly to changes in output (the output-accelerator effect) and very weakly or not at all to changes in the cost of capital. In other words, quantities rather than prices seem to matter for investment (Shapiro (1986), Blanchard (1986)).

Moreover, some empirical works cast doubt on the importance not only of the cost of capital on investment behaviour but of the output-accelerator also. In particular, in empirical implementations of investment models by Gordon and Veitch (1986) on U.S.A. data, and Ford and Poret (1990) on data from the seven biggest OECD economies, changes in output were found to be very sensitive to the inclusion of lags on the dependent variable in the model. The simple device of including such lags eliminated almost entirely the significant explanatory contribution of the accelerator\(^2\).

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\(^1\) We can recall only one study from the empirical investment literature in which expectations formation is affected by such additional variables, namely the study of Gordon and Veitch (1986).

\(^2\) Ironically, while Gordon and Veitch found the conventional variables to exhibit a small or none effect on investment behaviour, they found a large effect from the (unconventional) variables that entered the investment function because they contributed to the firms' formation of expectations as to the conventional variables.
As far as the $Q$ approach is concerned, the empirical implementation has revealed many econometric defects. Hence, the marginal $Q$ that the theory specifies is unobservable and it may markedly diverge from its frequently used proxy, the average $Q$. In addition, the $Q$ equation usually combines very low fit and very high serial correlation, while, although not predicted by the theory, lagged investment, lagged $Q$ and other explanatory variables have turned out to be significant (Abel and Blanchard (1986), Blundell et al. (1992), Fazzari, Hubbard and Petersen (1988)).

In this dissertation we investigate empirically the investment behaviour of Swedish manufacturing firms over the 1980s. We are primarily interested in identifying the factors that determine investment spending and in quantifying their magnitudes. The investigation covers only the domestic investment activity of the firms and is based on the flexible accelerator approach. As mentioned previously, the $Q$ approach has the advantage, compared to the accelerator approach, that the expectations formation mechanism of the firms need not be specified. However, as variable $Q$ summarises the effect on investment of all its determinants, the individual effect of each cannot be assessed. For that reason, we choose the accelerator approach instead of the $Q$ approach.

The line of research adopted in this dissertation aims to contribute to our understanding of the firms' investment behaviour through improvements in three respects. First, the empirical implementation is conducted at the firm level rather than at the aggregate level. The benefits from carrying out the empirical analysis at the disaggregate level have been discussed extensively in the literature (Hsiao (1985,1986), Griliches (1986), Klevmarken (1989)). Two of these benefits apply to our analysis. On the one hand, we avoid the aggregation problem associated with summation of variables over firms. On the other hand, we can control for the heterogeneity in the behaviour of individual firms. This heterogeneity emanates from differences in firms' individual attributes such as managerial ability, norms, and habits. In addition, we are able to test the validity of the theory at the level at which it is formulated. The utilised panel data comes from a survey conducted by The Industrial Institute for Economic and Social Research, IUI, Stockholm, and comprises major Swedish manufacturing firms observed yearly over the greater part of the 1980s. The data are used for first time for the purpose of investigating the firms' investment

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3 For an analysis of Swedish firms' demand for capital within an interrelated factor demand model, see Walfridson (1987, 1989) and Dargay (1988). For a presentation and analysis of Swedish firms' international investment behaviour, see Zejan (1988).
behaviour. Most importantly, the survey provides realised as well as quantitative expected or planned values of variables that are typically needed for the empirical implementation of investment demand equations.

Second, a new econometric methodology, suggested by Chamberlain (1982, 1984) and further developed by among others Bhargava and Sargan (1983), Bhargava (1987, 1991), Blundell and Smith (1989a, b), and Arellano (1990), is used for the empirical implementation of the economic theory. The methodology proposes the estimation and testing of models on panel data by drawing upon the analogy with the general simultaneous equations system. Since the econometric theory pertaining to the latter is well-developed, empirical analysis based on panel data is much favoured by this analogy.

Third, an attempt has been made to improve the functional form of the investment demand function on two counts. First, the functional forms of the mechanisms according to which firms forecast the future market conditions that concern them are determined empirically rather than imposed on an ad hoc fashion. These expectations formation mechanisms are of interest in themselves, but they are also necessary for the derivation of the investment demand equation since investment behaviour is an inherently forward-looking process. To this end, an empirical analysis of the firms' expectations formation processes is carried out based on the direct measures of firms' expectations provided in the survey. Contrary to the tradition in the empirical investment literature some additional variables beside the expectational variables' own past history are allowed to enter the expectations formation processes and, subsequently, the investment demand function. Second, the investment model is modified to account for the effects on investment spending of current and past expectations errors. In the case of boundedly rational agents, which is our maintained hypothesis, these errors contain relevant information not taken into account by the firm when it chooses the level of investment. We argue that expectations errors affect investment decision-making in two ways. On the one hand, through the partial revision of investment plans in the light of currently revealed expectations errors. On the other hand, through the degree of capacity utilisation which is the result of past uncorrected expectations errors.

The final form of the investment model includes the conventional variables of the neoclassical investment model, i.e. quantities (the output-accelerator effect) and prices (the cost of capital and the cost of labour). It also includes the cash flow variable which enters the model in order to capture the financial position of the firm. Furthermore, it includes two sets of unconventional variables. The first set comprises the additional
variables that enter the investment function through the expectations formation mechanisms. The second set comprises the variables that follow from the assumption of boundedly rational agents. Thus, in effect, our model stems from a behavioural framework which is wider than usually specified in the literature of firms' fixed investment behaviour. In addition, while the selection of explanatory variables is made on theoretical grounds, the dynamic specification of the investment model with respect to most of these variables is determined on empirical grounds.

1.1 Disposition of the Dissertation and Main Results

This dissertation develops as follows. Chapter 2 provides summary statistics of business fixed investment and its main determinants, as well as measures of uncertainty in the economic environment in Sweden and selected OECD economies over the last few decades.

Chapter 3 provides a description of the data and how the variables were constructed. Descriptive statistics of these variables are given in an Appendix to this chapter. Due to the great number of missing values in the data set, only a part of it could be utilised for the empirical analysis. As that might have introduced a selectivity bias into our sample, an informal test was carried out to settle that matter. The outcome of the test did not indicate that selectivity bias could be a serious problem. The chapter also contains a description of the econometric methodology used in the empirical implementations in subsequent chapters. Standard statistical packages contain procedures that can accommodate the estimation, but not the testing, of models along the methodology used in this dissertation. Hence, several statistical programmes were written by the author for the sake of the dissertation. In total, these programmes amounted to no less than two and a half thousand lines, and were written in SAS's programming language, IML.

Chapter 4 contains the empirical analysis of Swedish firms' expectations formation mechanisms. The expectations as to two variables are investigated: the hourly labour cost and the level of output. Two classes of models were used for the empirical analysis. The first class comprised four of the most frequently used purely extrapolative models, namely the first- and second-order adaptive model, Frenkel's error-correction model, and the simple acceleration model. For both variables, the models performed well in terms of the sign of the parameters and their significance. The specification of the simple accelerator
model was rejected by the test we carried out in the case of both variables. The specification of the other three models was not rejected, however, indicating the difficulty in discriminating among them on empirical grounds. Nevertheless, Frenkel's model turned out to be superior in terms of model fit.

The likely independent effect on firms' expectations formation of variables other than the expectational variables' own past history was subsequently investigated. To this end, two models from the class of augmented extrapolative models were implemented, one for the expected labour cost and one for the expected output. In the first model, current value added and current and lagged unfilled vacancies turned out to affect firms' expectations as to their labour cost, while expected output price was found to affect expectations as to the level of output. In addition, the tests that were carried out provided evidence in support for the specification of both models.

In Chapter 5 we set up an optimisation problem which postulates that the firm aims at minimising the expected present value of its total production costs, given its expectations of the demand for its output and of factor prices. The solution to the problem gives an investment decision rule from which a closed-form investment function is analytically derived, upon the substitution of the expectations formation mechanisms studied in the previous chapter. The investment function is subsequently modified (augmented) to allow for the effects of current and past expectations errors, and of the financial condition of the firm as it is described by its cash flow. The chapter presents the results from the empirical implementation of two models: the revision of investment plans model and the model of investment demand. With respect to the first model the results indicate that currently revealed expectations errors in the demand for output, but not in the cost of labour or the price of output, result into the revision of firms' investment plans. The test that was carried out provided evidence in support for the specification of this model.

The results from the estimation of the investment demand model were as follows. The data provided evidence in support for a significant output-accelerator effect on Swedish firms' capital formation. The data also indicated the significant effect of the cost of capital and the labour cost on investment spending. Moreover, an additional lag of the dependent variable turned out to be insignificant with minor effects on the parameters of the rest of variables. Thus, the data support the two conventional neoclassical determinants of investment which, in addition, were found not to be sensitive to the inclusion of lagged dependent variables. Evidence was found in support for a considerable effect of the price of output, but not so of the unfilled vacancies, on investment indicating the meaningfulness
in allowing economic agents to base their decisions on information sets that are broader than usually assumed in the literature. Contrary to what it was expected, the cash flow variable turned out to have no effect on firms’ investment behaviour. On the other hand, unused capacity was found to have a notable effect on investment spending, whereas currently revealed unfulfilled expectations, although significant, turned out to have a relatively weak effect on investment.

Finally, Chapter 6 contains a discussion.
Chapter 2

Capital Formation and its Determinants in the 1980s

2.1 Introduction

This chapter aims at providing a presentation and a discussion of the evolution of aggregate investment and some of its usually accepted determinants in Sweden and selected OECD countries over the past two to three decades. The chapter aims to serve as a macroeconomic background for the study of firms' investment behaviour in subsequent chapters. Although the analysis at the firm level is confined to investment performance during the 1980s, the presentation here covers a longer time period in an attempt to offer a better perspective. Furthermore, statistics for the major OECD economies and the Swedish economy are given for the sake of comparison. Where possible, development during the 1980s is divided in two sub-periods, 1980-83 and 1984-88, in order to account for the recession experienced by most OECD countries at the beginning of that decade.

2.2 Business Fixed Investment

Table 2.1 provides summary statistics of fixed investment in the business sector\(^4\) over the last three decades in Sweden and the seven major OECD economies. On the average, growth in gross investment expenditure in the major seven and in the OECD as a whole was lower during the 1980s than during the 1970s and less than half of the growth in the 1960s. This is mainly attributed to the stagnation of investment during the recessionary period in the early 1980s. Indeed, investment expenditures recovered sharply during the second half of the 1980s attaining an average annual growth of 6.9 per cent, almost as high as that during the vigorous 1960s. The picture is even more favourable for Sweden which

\(^4\) Business fixed investment is defined as private non-residential fixed capital formation.
<table>
<thead>
<tr>
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<th>Annual average growth rates, volume</th>
<th>As a per cent of business sector value-added</th>
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<tr>
<td></td>
<td>Gross business fixed investment</td>
<td>Gross business fixed investment</td>
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<td>United States</td>
<td>6.0</td>
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<td>Japan</td>
<td>17.8</td>
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<td>Germany</td>
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<td>France</td>
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<td>Major 7</td>
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<td>OECD Total</td>
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<td>3.9</td>
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1 Private non-residential fixed capital formation.
2 Business sector value-added is defined as GDP at factor cost less the deflated government sector wage bill and (where available) government sector capital cost allowance.
3 Germany, Italy, Canada, and Sweden from 1961. France from 1964.
experienced annual growth above the averages for the OECD and the major seven economies in both sub-periods of the 1980s. During the second half of the 1980s, in particular, gross capital formation in Sweden soared to 7.1 per cent per year, almost twice its own growth rate during the 1960s. Comparison with the other major economies reveals that during the period 1984-88 Sweden achieved the best investment performance in relation to its own investment performance in the 1960s.

Table 2.1 also provides summary statistics of gross and net business fixed investment\(^5\) as a per cent of business sector value added\(^6\). These ratios are much less volatile than the previous growth rates. Gross investment-output ratios remained essentially unchanged over the 1980s compared to the 1970s for both the OECD as a whole and for the major seven, while for the latter these ratios were slightly lower compared to the 1960s. On the contrary, net investment-output ratios have been falling continuously since the 1960s resulting in declining capital-output ratios. This follows from the definition of net investment as the addition to the productive capital stock. Swedish gross and net investment-output ratios were higher than average in the 1980s. The average rate in the former was about 17 per cent per year compared to annual average rates of about 16.4 for the OECD and the major seven, while the average rate in the latter was about 9.4 compared to 8.5 and 8.4 for the OECD and the major seven, respectively. Over the second half of the 1980s in particular, Sweden attained an average investment-output rate that was higher than in any previous period since the beginning of the 1960s. Moreover, Sweden ranked third among the major industrialised countries in improving its investment ratios for the period 1984-88 as compared to the 1960s, preceded by Canada and the United States.

The investment rates presented in Table 2.1 concern only fixed tangible capital formation and therefore ignore investments in other kinds of assets such as intangible capital and financial assets. Investments in intangibles refer to expenditures in research and development (R&D), computer software, training and education, etc. These kinds of investments are similar to investments in fixed capital except there is no physical stock. Available data on investment in real R&D reveal that during the period 1970-79 the ratio of business R&D to business investment expenditure was 9.7 per cent per year in the OECD as a whole, while during the period 1980-88 the same ratio increased to 12.4 per cent per

\(^{5}\) Net investment is here defined as gross investment less scrapped capital.

\(^{6}\) Business sector value-added is defined as GDP at factor cost less the deflated government sector wage bill and (where available) government sector capital cost allowance.
Figure 2.1: Financial Assets as Percent of Total Assets


Note: Financial assets are defined as the sum of shares and participations in group companies and non-related companies, long-term receivables from group companies, and other long-term receivables.
The corresponding ratios for Sweden in the two periods were 9.1 and 15.1 per cent per year, respectively. Furthermore, from ranking fifth in the first period Sweden ranked third in the second period among all the OECD economies preceded only by the US and Germany.

Investment expenditures on financial assets have increased markedly over the past two decades. Figure 2.1 shows the evolution of the share of the stock of financial capital in the total stock of capital. Over the period 1970-79 this share was on an average 39.6 per cent, while over the period 1980-88 it soared to 53.4 per cent. In 1988 the stock of financial assets was no less than 61.2 per cent of the total capital stock. An explanation for this development can be found in the attractive returns on financial assets in the Swedish money and capital markets. As we will see below, the Swedish real long-term interest rate attained very high levels during the second half of the 1980s and the same is true for the return on stocks in the Stockholm Stock Exchange, the index of which increased on the average by 30 per cent per year over the period 1980-88.

Although the development of the volume of Swedish business fixed investment over the 1980s kept pace with that in the rest of the OECD area, there is evidence that some qualitative characteristics of the country's capital stock deteriorated. Specifically, results by Bentzel (1991) indicate that over the 1980s the portion of investment aiming at improving the efficiency of the production process fell while that aiming at expanding it increased compared to previous periods. Moreover, during this period, capital stock became older.

2.3 Determinants of Investment Expenditures

Table 2.2 provides summary statistics of unemployment rates in manufacturing. Unemployment rates increased markedly during the 1980s compared to earlier periods for both the OECD as a whole and for the major seven countries. This is true of both the recessionary period 1980-83 as well as for the recovery period 1984-88. On average, the unemployment rates in the two areas over the entire 1980s were almost three times as high as for late 1960s. The increase in the Swedish unemployment rate was considerable lower

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7 The figures on real R&D expenditures were assembled by the OECD Directorate for Science, Technology and Industry and are reported in Ford and Porter (1990).

than the rest of the industrialised countries. This rate was on the average 2.6 per cent per year over the 1980s, markedly lower than for the OECD as a whole (7.4 per cent) and the major seven economies (7.7 per cent).

Table 2.2: Standardized unemployment rates

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Note: For periods 1966-69 and 1970-79 the OECD figures refer only to the major seven and the following countries: Australia, Austria, Belgium, Finland, the Netherlands, Norway, Portugal, Spain and Sweden.

The implied tightening in the Swedish labour market gave rise to a considerable shortage of skilled labour over the greater part of the past decade. As reported by the OECD\(^9\), business surveys revealed that in 1982, 15 per cent of Swedish firms surveyed

\(^9\) OECD Economic Outlook, 46, December 1989.
reported a shortage of skilled labour. In 1988 the percentage had increased to 60. This is to be compared with a 30 per cent shortage in Finland, 22 per cent for the U.K., and less than 10 per cent in Norway, Canada and Ireland.

Table 2.3: Average real hourly earnings in manufacturing

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The shortage of labour could offer an explanation for the development of real hourly earnings\textsuperscript{10} in the Swedish manufacturing sector. As reported in Table 2.3 these earnings increased by 1.8 per cent per year during the period 1984-88, while they decreased by 2 per cent per year for the period 1980-83. For the major seven countries the development was the opposite. Both for Sweden and the major seven, however, real hourly earnings fell markedly over the 1980s as compared to the 1960s and the 1970s.

\textsuperscript{10} Real hourly earnings are defined as nominal hourly earnings of salaried employees as well as wage earners less inflation as measured by the CPI.
Table 2.4: Industrial Production

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Summary statistics of industrial production are presented in Table 2.4. For Sweden as well as for the major seven economies, industrial production fell during the 1980s compared to earlier periods with signs of recovery during the second half of that decade. Nevertheless, the high levels of the 1960s were yet to be achieved. Despite the weak demand of industrial output, capacity utilisation in the Swedish manufacturing sector was rather high over the 1980s. During 1980-83, 81.4 per cent of the capacity was utilised, while for 1984-88, 87.4 per cent was utilised. This is to be compared with an average utilisation of 70.8 and 79.1 per cent for the two periods, respectively, in the major seven area.

---

11 Statistics Sweden I 13 SM 9001.
12 OECD Economic Outlook, 46, December 1989.
The evolution of real long-term interest rates is shown in Table 2.5. Interest rates increased substantially during the past decade both in the major seven area and in Sweden. For the former, real interest rates averaged 4.2 per cent per annum over the 1980s and for the latter 3.8 per cent per annum over the same period. The increase was dramatic in the second half of the 1980s. Interest rates for the major seven averaged almost twice as much as during the 1960s, while for Sweden the average rate was 2 1/2 times the rate in the 1960s. In addition, for the first time for 1984-88, the average Swedish real interest rate exceeded the average rate in the rest of the industrialised countries. It is in this development of interest rates that the explanation for increased interest in investments in financial assets in Sweden could be found.

### Table 2.5: Real long-term interest rates

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13 Real long-term interest rate is defined as yields to maturity of long-term government bonds less the percentage change of consumer prices from previous year.

2.4 Uncertainty in the Economic Environment

Apart from the evolution of levels of different economic variables, their variability should be expected to affect investment decision-making. On the presumption that uncertainty is related to the volatility of these variables, an increase in the latter would imply a deterioration of the investment climate.

Ford and Porter (1990) have estimated two measures of uncertainty for different OECD countries and for four key macroeconomic variables: industrial production, consumer prices, the real long-term interest rate, and the nominal effective exchange rate. The first measure is an *ex post* measure equal to the standard deviation of the rate of change of each of the variables and for each country. Since a low (high) *ex post* volatility may not necessarily imply a low (high) *ex ante* prediction error, as a second measure of uncertainty the standard deviation of one-step-ahead forecast errors was used. To this end, simple ARIMA time-series models were estimated for the seven largest OECD countries and for each of the four series. Both measures were estimated for four time periods, 1960-74, 1974-78, 1979-82, and 1983-89 and are given in Table 2.6. For most of the major seven countries the volatility of the first three variables was lower in 1983-89 than in previous periods. In contrast, nominal exchange rates tended to be more volatile recently for most countries. For Sweden, consumer prices and real long-term interest rates have been less volatile for 1983-89 as compared to the other three periods, while industrial production and the nominal effective exchange rate were negligible higher than in 1960-73 and notably higher than in the other two periods. Hence, if the climate for investment decision-making is affected by the volatility of these macroeconomic variables, then the figures clearly show that this climate was really mild in Sweden during the 1980s.

2.5 Summary

The summary statistics presented in this chapter showed that the Swedish business fixed capital formation over the 1980s was on an average higher than that within the OECD area as a whole and the major seven industrial countries. This is particularly true for the
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(Table 2.6 continues)
(Table 2.6 concluded)

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| Canada | 1960s-73 | 1.38     | 1.93     | 2.21     | 1.51     | 1.29     | 0.73     | 1.66     | 1.53     |
|        | 1974-78  | 1.29     | 1.61     | 2.01     | 1.28     | 0.37     | 0.73     | 1.66     | 1.57     |
|        | 1979-82  | 0.64     | 0.58     | 0.45     | 0.28     | 1.29     | 0.73     | 1.66     | 1.57     |
|        | 1983-89  | 0.38     | 0.50     | 0.33     | 0.37     | 1.29     | 0.73     | 1.66     | 1.57     |
|        |          | 1.25     | 1.70     | 1.18     | 1.29     | 0.51     | 0.91     | 0.91     | 0.91     |
|        |          | 0.51     | 0.91     | 1.03     | 0.73     | 0.91     | 0.91     | 0.91     | 0.91     |
|        |          | 2.22     | 1.66     | 1.37     | 1.66     | 1.66     | 1.57     | 1.57     | 1.57     |
|        |          | 1.66     | 1.57     | 1.57     | 1.57     | 1.66     | 1.57     | 1.57     | 1.57     |

| Sweden | 1960s-73 | 2.03     | 2.27     | 2.80     | 2.04     |        |        |        |        |
|        | 1974-78  | 0.82     | 1.11     | 1.13     | 0.67     |        |        |        |        |
|        | 1979-82  | 1.55     | 1.69     | 2.65     | 1.36     |        |        |        |        |
|        | 1983-89  | 0.87     | 2.48     | 4.02     | 0.97     |        |        |        |        |


Notes: (a) Nominal rate less year-on-year rates of change in consumer prices.
(b) Standard deviation of quarterly rates of change over each sub-period.
(c) Standard deviation of the differences between the actual values and one-step-ahead forecasts using ARIMA models.

During the period 1984-88 during which Sweden not only exceeded the averages for the two areas but also exceeded its own investment rate in any other of the previous periods since the early 1960s considered here. Yet, it is worth noticing two aspects of the Swedish fixed capital formation during the 1980s. Firstly, investments in financial assets have been increasing during this period and in 1988 they were equal to 61.2 per cent of the total capital stock. Secondly, the portion of investment aiming at expanding capacity rather than improving the efficiency of the production process has increased.
The tightening in the Swedish labour market along with a considerable shortage of skilled labour has probably had a discouraging effect on firms decision to invest in new capital. Following the international business cycle, the rate of growth of the Swedish industrial production slowed down in the 1980s with a notable tendency to recover for 1984-1988. Yet, similar to the major seven group, Sweden had still to attain the rates of growth for industrial production of the vigorous 1960s. Real long-term interest rates have been twice as high in the 1980s compared to the 1960s in the major seven area. For Sweden, the increase has been even higher and for first time since the early 1960s the Swedish real interest rate exceeded that of the major industrialised countries. Finally, the volatility of four key macroeconomic variables has been moderate over the 1980s compared to earlier periods. To the extent that low volatility implies low uncertainty, the economic environment should have contributed positively to the Swedish climate for investment decision-making.
Chapter 3

Data and Econometric Methodology

3.1 The Data Set

The empirical analysis of the firms’ investment behaviour is based on survey data collected by The Industrial Institute for Economic and Social Research, IUI, Stockholm. The survey comprises 322 manufacturing firms observed yearly over the period 1980-1989. The firms included in the survey represent production establishments and, as such, groups of companies are broken up into their constituent production units. The greater part of the firms are quoted on the Stockholm Stock Exchange. The great advantage with this data set is that it includes realised as well as expected values of several variables. Observations on realised values cover the period 1980-1988, while those on expected values, the period 1981-1989. Values on all the variables that are used in the empirical implementations are available at the firm level from the survey except for three: the price indices for intermediate goods and investment goods, and the real long-term interest rate. Aggregate data, obtained from available sources, on these variables were used instead (see the list of variables later in this chapter). One problem with the survey data is the great number of missing values due to non-response. The missing values are spread all over the data set with their frequency increasing when it comes to firms’ plans and expectations. When the firms with many non-responses had been dropped from the data set, we were left with 93 units that had regularly participated in the survey over the period 1982-1988. However, since the values of many variables happened to be available for 1981, when necessary these values were also used in the estimation. This is particularly true for the realised values of the variables for which the frequency of non-response was low.

The issue of non-response could have been left here if it was not for the risk that a selectivity bias may have arisen in the sample. This kind of bias may arise when the sample is not drawn randomly from the whole population but is, instead, a sample from a sub-set of the population. The latter case occurs when the members of the population must meet
some conditions in order to have the possibility of being included in the sample. An example of this could be that a firm must undertake a certain level of investment if it is to be included in the sample. When the truncation is based on the level of investment, uses of the data that treat this variable (or components of it) as a dependent variable will often create what is referred to in the literature as selection bias (Heckman (1976, 1979), Hausman and Wise (1977), McFadden (1984)).

Selection bias may also arise in the case of non-response if the probability to respond hinges on variables that are treated as dependent. Although the truncation is not imposed by the analyst, it may have been "imposed" by the non-respondents themselves. It is therefore of interest to look for evidence of selectivity bias in a sample with non-responses. Recalling that in our survey the non-responding firms did not respond in some years while they responded in others, we can compare the mean values of our dependent variables in the preferred sample with the mean values of the same variables for all the responding firms for some specified years with high response frequency. A small difference in the mean values of the two groups could be interpreted as an indication that the probability of non-response does not heavily depend on these variables. If, on the other hand, the difference is large, the opposite would be indicated implying the possibility of selection bias in the sample. The variables that are treated as dependent in subsequent empirical implementations are the expected hourly labour cost, $E$, the planned production volume, $Q^*$, and the actual real net investment level, $I$. Unfortunately, the latter cannot be constructed for firms not included in the preferred sample. The reason is that although there is information on these firms' gross investment spending, there is no information on their net capital stock and thus replacement investment cannot be calculated. Instead, real gross investment, $I^G$, has been used for the sake of the present investigation.

We have selected two time periods at which we conducted the comparison; one at the beginning of the survey (1982) and one at the end of the survey (1988). Variable $Q^*$ is not readily available from the survey. Its construction (described in the next sub-section) demands information from series on four different variables. In addition, two of these series have to be complete, i.e., they should not include missing values at all, since the construction of $Q^*$ on any time period is based on its value in the preceding period. Therefore, in the late years of the survey, $Q^*$ could be calculated only for the firms that participated regularly in the survey. These firms are the 93 units in the preferred sample. Comparison with non-regularly participating firms for 1988 is thus not possible. Finally, in order to facilitate comparison of firms with different size, variables $Q^*$ and $I^G$ were normalised with the actual number of employees, $E$. 

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Mean values of $W^*$, $I^G/E$, and $Q^*/E$ for 1982 and 1988 and for the two groups of firms are shown in Table 3.1. The first group comprises the 93 firms in the preferred sample, while the second group comprises the firms that did not participate regularly in the survey but happened to have responded in the two selected years.

**Table 3.1**

**Mean Values of Dependent Variables in Two Groups of Firms,**  
 **for 1982 and 1988**

<table>
<thead>
<tr>
<th></th>
<th>1982</th>
<th>1988</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>Mean Value</td>
</tr>
<tr>
<td>$W^*$</td>
<td>93</td>
<td>85.42</td>
</tr>
<tr>
<td></td>
<td>181</td>
<td>82.14</td>
</tr>
<tr>
<td>$I^G/E$</td>
<td>93</td>
<td>22.28</td>
</tr>
<tr>
<td></td>
<td>181</td>
<td>22.16</td>
</tr>
<tr>
<td>$Q^*/E$</td>
<td>93</td>
<td>583.66</td>
</tr>
<tr>
<td></td>
<td>152</td>
<td>517.90</td>
</tr>
</tbody>
</table>

**Notes:** N = Number of firms in the group.

Definition of variables: $W^*$ = Expected hourly labour cost, current SEK; $I^G/E$ = Real gross total investment normalised by actual employment level, thousand SEK; $Q^*/E$ = Planned production volume normalised by actual employment level, thousand SEK.

There are no substantial differences in the mean values of $W^*$ and $I^G/E$ between the two groups of firms. Interpreting this as an indication that the probability of non-response does not hinge on these variables, treating them as dependent variables in forthcoming models should not result in a selectivity bias. As long as variable $Q^*/E$ is concerned, however, we notice that the mean value for the firms in the preferred sample is about 12 per cent higher as compared to the mean value for the rest of the firms. To the extent that
this difference indicates a dependence of the probability of non-response on $Q^*/E$, treating the latter or components of it as a dependent variable could give rise to selectivity bias and, thus, the estimation results should be interpreted with some caution.

3.2 List and Construction of Variables

The source of data is the firm survey of The Industrial Institute for Economic and Social Research, IUI, Stockholm, unless otherwise stated. Where variables are not directly provided by the survey their construction is described. Descriptive statistics are shown in Appendix 3.A.

$\Delta{}(\ ) = \text{Difference per time unit.}$

$W = \text{Labour cost per hour including employers' contribution to social security. It is constructed as the ratio of total labour cost over total working hours. Information on these two variables is readily available from the survey.}$

$W^* = \text{Expected labour cost per hour including employers' contribution to social security. Its construction parallels that for } W \text{ with the difference that expected values were substituted for actual values. Information on expected total labour cost is also readily available from the survey.}$

$Q = \text{Production volume. In the survey, the firms provide information on their total sales, finished-goods inventories and the percentage change in production volume from the previous year. In order to construct variable } Q, \text{ its value for 1981 was first calculated as total sales for that year corrected for the change in finished-goods inventories for the same year. The 1981 production volume was then used as a bench-mark for the construction of the whole series of } Q \text{ utilising the percentage change in this variable provided by the firms.}$

$Q^* = \text{Planned production volume. In the survey, the relevant question for the construction of this variable asks for the planned percentage change of production volume from the previous year. Variable } Q^* \text{ was thus constructed by multiplying each year's planned percentage change of production volume by the previous year's actual production volume.}$
\( I \) = Sum of real net investment in machines and construction. Nominal gross investment in each kind of asset is provided from the survey. Published investment-goods price indices for each kind of asset were used to obtain real gross investment in machinery and construction from which the depreciation of real beginning-of-period net stock of each asset was subsequently subtracted.

\( IREV \) = Investment revision. It is constructed as the difference between planned and actual real net total investment. The construction of the former parallels that of the latter, but with nominal planned gross investment in each asset instead of nominal actual gross investment. Nominal planned gross investment was readily available from the survey.

\( K \) = Real total net capital stock. It equals the sum of real net capital stock of machinery and construction. Variable \( K \) was constructed by the perpetual inventory method. According to this method, gross investment is accumulated over time taking into account the depreciation of older capital. The net capital stock is calculated as:

\[
K_{t+1} = (1 - \delta)K_t + I_t,
\]

where \( K \) is the net capital stock at the beginning of period \( t \), \( I \) is gross investment during the period, and \( \delta \) is the depreciation rate. The net capital stock of each kind of asset and for any period can be constructed given information on the rate of the assets' depreciation, a series on gross investment in each asset and the value of each asset's net capital stock for a particular year which serves as a bench-mark. The depreciation rates of each firm's machinery and construction in 1988 are available from the survey. On the assumption that these rates remained constant over the 1980s, their values for the rest of this period were set equal to the values in 1988. Hence, the depreciation rates vary over firms but stay the same through time.

Each firm's total nominal net capital stock in 1988 is also available from the survey. However, the shares of the stocks of the two kinds of assets in the total stock are not known. Since different depreciation rates and different price indices apply to each kind of asset, the application of the above formula is not possible when the shares are unknown. As a matter of fact, we need only know the shares of the two assets in the total in one year. Since this information is
not available at the disaggregate level, we will approximate the shares of the stocks in the total capital of each firm by the corresponding shares at the aggregate level. In order to minimise the implied measurement error, this approximation will be made in a year prior to the first observation on capital stock used in forthcoming empirical implementations. The following procedure was applied for the calculation of the two assets net capital stock:

The formula above can be rewritten as follows:

\[ K_{t+i} = (1 - \delta)^t K_t + \sum_{i=1}^{M} \left( 1 - \delta^M \right)^i I_t^M + \sum_{i=1}^{C} \left( 1 - \delta^C \right)^i I_t^C \]

where the superscripts \( M \) and \( C \) stand for machinery and construction, respectively. Let the subscript \( t+i \) stand for 1988 (the year for which nominal net capital stock is available). Utilising the series on gross investment, beginning in 1981 for the two kinds of assets, transformed to 1988 year’s prices, we can solve the above expression for the value of \( (1 - \delta)^t K_t \), which thus pertains to the total capital stock at the beginning of 1981, in 1988 year’s prices. The shares of the stocks of the two kinds of assets in \( K \) (and of the two depreciation rates in \( \delta \)) were then set equal to the shares of the two assets in total net capital stock at the aggregate branch level. These shares were obtained from unpublished data assembled by the Swedish Bureau of Statistics. Thus, each firm’s stock of machinery and construction at the beginning of 1981 can be estimated. Given these stocks, the series on gross investments, the depreciation rates and the price indices, the two capital stocks for the whole period in 1981 year’s prices were constructed.

\[ \begin{align*}
CU &= \text{Capacity utilisation in percent of full capacity. Readily available from the survey.} \\
VA_H &= \text{Value added per hour. It is constructed as the ratio of value added over working hours per employee times the number of employees. The last two variables are readily available from the survey. Value added was constructed as sales less expenses for intermediate goods.} \\
L &= \text{Actual employment level. Readily available from the survey.}
\end{align*} \]
UNVAC = Unfilled vacancies. It is constructed by taking the ratio of the difference between planned and actual employment level, over the actual employment level and multiplied by one hundred. Values on both planned employment level and actual employment level are readily available from the survey.

CF = Cash flow. It is constructed as value added minus total labour cost, less taxes which were arbitrarily set equal to 30 per cent of this difference.

PM = Intermediate goods price index, purchasers' values, branch-wise. Swedish National Accounts, Appendix 4, N 10 SM 8901.

PL = Labour cost index including employers' contribution to social security. The index is based on the variable $W$ which is the hourly labour cost including employers' contribution to social security. For the construction of $W$ see above.

PL' = Index for expected labour costs. The construction of this variable parallels that of PL with the difference that it is based on $W'$ rather than $W$. For the construction of $W'$ see above.

PI = Weighted average of investment goods price index for machines and construction. The weights are firm-specific, equal to the relative share of the two kinds of assets in the firm's real current gross total investment. The branch-wise price indices for machines and construction were obtained from the Swedish National Accounts, Appendix 2-3, N 10 SM 8901.

P = Output price index. It is constructed from the series of output in current prices and output volume. The latter is described above ($Q$), while output in current prices was constructed from the series of sales and of changes in inventories.

P* = Index for expected output price. It is constructed as the weighted sum of the indices for expected output price at home and abroad with weights equal to the relative share of expected sales at home and abroad in total expected sales. Firms' expectations of their output prices at home and abroad as well as their expected sales at home and abroad are readily available from the survey

$w = \frac{PL}{PM}$.

$w^* = \frac{PL^*}{PM}$.
\( p = P/PM. \)

\( p^* = P^*/PM. \)

\( q = PI/PM. \)

\( r = \) Nominal long-term interest rate defined as yields to maturity of long-term Swedish government bonds.  

\( \delta = \) Weighted average of depreciation rates of machines and constructions. The weights equal the relative share of the stocks of the two kinds of assets in real beginning-of-period net total capital stock.

\( \pi = \) Percentage change of Swedish Consumer Price Index from previous year.  

\( \bar{q} = \) \( q(r - \pi + 0.04 + \delta) \) where 0.04 is an arbitrary risk premium.

### 3.3 Econometric Methodology

Contrary to the estimation and testing of economic models at the aggregate level, empirical analysis at the disaggregate level calls for particular attention to two specific issues. The first issue concerns the heterogeneity in the behaviour of individual economic agents. This heterogeneity emanates from unobservable individual-specific attributes such as ability, habits, norms and states of mind, usually assumed to remain invariant through time but to vary over individuals. The second issue arises from the fact that typical panel data comprise a great amount of cross-sectional units but observed over a short period of time. The implication of this is that standard estimators which rely upon the increase in the number of time periods for their desirable asymptotic properties may perform unsatisfactorily when the number of observations in the sample is small. Hence, the relevant question in the estimation of models on panel data is whether, or under what conditions, these estimators can still enjoy their desirable asymptotic properties when relying upon the increase in the number of individual units. Econometric literature has discussed extensively these issues and has suggested estimation techniques that cope with cases where
the performance of standard estimators is not regarded as satisfactory. The purpose of this section is to present such a technique which will be used in the empirical implementations in subsequent chapters.

Standard time-series econometric models are usually interpreted as being derived from the conditional distribution function of the dependent variable given a set of explanatory variables. Prior to conditioning, a marginalisation has been made with respect to every variable that can safely be assumed not to exert any considerable effect on the model under investigation. Specifically, assuming that $\zeta$, denotes a very large vector of variables, in principle every conceivable economic variable, it can be split up into three parts, $\zeta_t' = (w_t', y_t, x_t')$, where $w_t$ denotes a vector of variables that is irrelevant for the empirical analysis at hand and therefore will be integrated out (i.e., with respect to which the analysis is marginalised), $y_t$ is the variable that will be modelled, and $x_t$ is a vector that will be treated as exogenous for the purpose of the analysis (i.e., on which the analysis is conditional). The marginalisation with respect to $w_t$ can be written in terms of the distribution function of $\zeta_t$:

$$D(z_t | Z_{t-1}, \theta) = D(w_t | y_t, x_t, Z_{t-1}, \phi_1) \cdot D(y_t, x_t | Z_{t-1}, \phi_2). \quad (3.1)$$

Ignoring the marginal distribution $D(w_t | y_t, x_t, Z_{t-1}, \phi_1)$ in (3.1), one can concentrate solely on the conditional distribution $D(y_t, x_t | Z_{t-1}, \phi_2)$ which can be factorised as:

$$D(y_t, x_t | Z_{t-1}, \phi_2) = D(y_t | x_t, Z_{t-1}, \lambda_1) \cdot D(x_t | Z_{t-1}, \lambda_2). \quad (3.2)$$

In expressions (3.1) and (3.2), $D(\cdot | \cdot)$ denotes a distribution function, $Z_t' = (Z_{0}', Z_t')$ where $Z_{0}' = (z_1, \ldots, z_t)'$ are the observed data on vector $\zeta_t$ up to time period $t$ and $Z_0$ is the matrix of unobserved data on vector $\zeta_t$, i.e. for time periods prior to the first observation of the available sample, also called unobserved initial conditions. Vector $\theta$ in (3.1) is a parameter vector with appropriate reparameterisation $(\phi_1, \phi_2)$. Similarly, $\phi_2$ is reparameterised as $(\lambda_1, \lambda_2)$ (Hendry and Richard (1983), Hendry et al. (1984)). In (3.2) we assume that matrix $Z_{t-1}$ does not include lagged values of $w$ but only of $y$ and $x$ which means that $w$ does not Granger-cause $y$. In addition it is usually assumed that the sample contains a sufficient number of observations so that the effect of the unobserved past history of vector $\zeta_t$, i.e. matrix $Z_0$, can be ignored. So, matrix $Z_0$ is dropped from $Z_{t-1}$. 

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Now, under the assumption of appropriate marginalisation in (3.1), and functional independence between $\lambda_1$ and $\lambda_2$ in (3.2), the empirical analysis can be based solely on the conditional distribution function in (3.2):

$$D(y_t | x_t, Z_{t-1}, \lambda_1).$$

(3.3)

while leaving the marginal distribution function unspecified. The conditional distribution (3.3) is usually specified as a linear function of $x_t$ and $Z_{t-1}$, though this specification is strictly valid only if the distribution of $y_t$ belongs to the class of exponential distributions (e.g., normal or $t$). Under the conditions stated above the parameters of the conditional distribution can be estimated consistently by the Least Squares or the Maximum Likelihood estimation method.

The conditional function (3.3) postulates that the dependent variable $y_t$ is driven by some purely economic factors described by variables $x_t$ and $Z_{t-1}$. It is, however, reasonable to assume that at the disaggregate level, agents' behaviour is also driven by individual-specific attributes such as ability, habits and conventions. These attributes are inherently subject to laws of inertia and therefore expected to change rather slowly through time, but they may vary markedly over individuals. The latter gives rise to the heterogeneity in the behaviour of economic agents.\footnote{Although these remarks pertain particularly to analyses of economic behaviour at the level of individual agents, Pesaran (1985) found evidence of non-economic factors in an inflation expectations model at the aggregate level.}

In order to address the issue of heterogeneity properly, we postulate an error-component model which can facilitate the inclusion of individual-specific attributes:

$$y_{it} = \alpha + \beta x_{it} + u_{it}$$

$$u_{it} = \eta_{it} + \epsilon_{it}.$$  

(3.4)

In (3.4), $t=1,2,...,T$ is the number of observations in the sample, $i=1,2,...,N$ is the number of cross-sectional units, i.e., the number of individuals in the sample, $y_{it}$ is the dependent variable, and $x_{it}$ is a vector of explanatory variables. Both $y_{it}$ and $x_{it}$ vary over time and individuals. The error term $u_{it}$ consists of two components. The first component is the random process $\epsilon_{it}$ (the transitory component) which is the usual error process of
the model and is supposed to capture all the independent and insignificant effects not included in the model. This process generates different values through time and over individuals. The second component is the random process \( \eta_t \) (the permanent component) which is a (unobservable) process that aims at representing individual time-invariant effects that are the same for a given cross-sectional unit through time but that vary across cross-sectional units.

The individual effects \( \eta_t \) can, for practical reasons, be regarded as deviations from the overall arithmetic mean of all the individual effects. In this case intercept \( \alpha \) is the sum of both the overall mean value of \( \eta_t \) and the conventional intercept of the model. Hence, the effects \( \eta_t \) have zero means by construction, and we will assume that they are distributed independently across individuals, with constant variance \( \sigma^2_\eta \). The transitory component \( \epsilon_{it} \) is assumed independently and identically distributed with zero mean and constant variance \( \sigma^2_\epsilon \). Furthermore, given the assumptions about the generation of \( \epsilon_{it} \), we can safely assume that the latter is independent of the effects \( \eta_t \). Due to the assumption of time-invariant individual effects, the covariance matrix of \( \upsilon = (\upsilon_{it}, \ldots, \upsilon_{IT}) \) is non-diagonal and is given by:

\[
\text{Var}(\upsilon_i \upsilon_i') = E(\upsilon_i \upsilon_i') = \sigma^2_\epsilon I_T + \sigma^2_\eta \epsilon \epsilon',
\]

where \( \epsilon \) is a \( T \times 1 \) vector of ones. Under the assumption of independence between the error term \( \upsilon_{it} \) and the explanatory variables in vector \( \chi_{it} \), estimation of (3.4) by the Generalised Least Squares method (GLS) using the covariance matrix (3.5) yields unbiased and efficient parameter estimates. As the variance components \( \sigma^2_\eta \) and \( \sigma^2_\epsilon \) are typically unknown, they may be substituted by some consistent estimates without loss of asymptotic efficiency (Hsiao (1986)).

The assumption of independence between the explanatory variables and the error term is frequently violated in panel data analyses due to the fact that the individual effects are often correlated with some of the explanatory variables (Mundlack (1978)). Failure to take due account of this correlation will render the GLS estimator biased. Moreover, for a fixed number of time periods \( T \), the GLS estimator will be inconsistent if the correlation does not vanish as the number of cross-sectional units \( N \) tends to infinity (Hausman and Taylor (1981)).
As we mentioned previously, when models are estimated on time-series data, the unobservable past history of the economic relationship that is estimated is usually ignored on the assumption that it does not affect the performance of the estimators. In dynamic panel data analyses, this assumption cannot be maintained as the number of observations is typically small, while dynamic processes depend on their past history by definition. Several authors have been concerned with this issue pointing out that for fixed $T$, the consistency property of the GLS estimator as $N$ tends to infinity, crucially depends on the assumption made on the initial observations on the dependent variable (Anderson and Hsiao (1981, 1982), Nerlove (1971), Nickell (1981), Sevestre and Trognon (1985)). In particular, consistency is retained only if we are prepared to assume that the initial observations are fixed or random but independent from the past history of the process. This assumption is very restrictive since the decision of when to start sampling is in most cases arbitrary. Under the more realistic assumption that the process is dependent of its past, the GLS estimator for fixed $T$ and $N$ tending to infinity is inconsistent (Sevestre and Trognon (1985)). Consistency of the GLS estimator is retained if the dependence of the process on its past history is explicitly taken into account during the estimation. In other words we need to explicitly specify the initial conditions of the model.

The need to model both the initial conditions and the correlation of the unobservable individual effects with some of the explanatory variables has led panel data analysts to suggest a framework for the estimation of dynamic relationships from panel data by drawing upon the analogy with the general simultaneous equations system. Indeed, as first suggested by Chamberlain (1982,1984) and followed by among others Bhargava and Sargan (1983), and Blundell and Smith (1989a,b), in the typical case of a longitudinal sample with a big amount of cross-sectional units $N$ repeated successively in $T$ time periods we may regard the problems that arise in the estimation and testing of this model as akin to those of a simultaneous equations system with $T$ structural equations and $N$ observations available on each of the equations. Furthermore, since the theory of identification, estimation, and testing is well-developed for simultaneous equations systems, it is possible to extend the relevant theorems to panel data. So, the fact that the $T$ equations are identical implies that there are cross-equations linear restrictions on the parameters of the system the estimation of which is easily undertaken within existing system estimation procedures. Making due use of these cross-equation restrictions, the system can be identified even in cases in which it might seem unidentified from the use of conventional criteria. The imposition of the restrictions also allows the use of the exogenous variables which are included in the system, as instruments for the variables that are correlated with the individual effects as well as
for the modelling of the initial condition (Hausman and Taylor (1981), Bhargava (1991)). This is in contrast with the conventional simultaneous equations model in which excluded exogenous variables are required to identify and estimate the parameters of the system.

In particular, a panel data model for each cross-section unit \( i \) can be written in the following simultaneous equations form:

\[
\begin{align*}
-\mathbf{y}_{0i} + \sum_{t=0}^{T} \mathbf{u}_i \mathbf{x}_{1it} &= \mathbf{v}_{0i} \\
B\mathbf{y}_i + \sum_{t=1}^{T} \mathbf{C}_t \mathbf{x}_{2it} + \sum_{t=1}^{T} \mathbf{C}_1 \mathbf{x}_{1it} &= \mathbf{v}_{1i} \\
-\mathbf{x}_{2it} + \sum_{j=0}^{T} \mathbf{F}_{ij} \mathbf{x}_{1ij} &= \mathbf{v}_{2it} \\
\end{align*}
\]

where \( i = 1, \ldots, N, t = 1, \ldots, T, \mathbf{y}_{0i} \) is the vector of initial values of the dependent variable the dimension of which is equal to the number of lagged dependent variables on the right-hand side of the model, \( \mathbf{y}_i \) is a \( T \times 1 \) vector of the dependent variable, \( \mathbf{x}_{2it} \) are the \( k_2 \) explanatory variables that are correlated with the individual effects, \( \mathbf{x}_{1it} \) are the \( k_1 \) explanatory variables that are uncorrelated with the effects, \( \mu_i \) are \( k_1 \times 1 \) coefficient vectors, \( \mathbf{C}_1 \) and \( \mathbf{C}_2 \) are respectively \( T \times k_1 \) and \( T \times k_2 \) coefficient matrices, \( \mathbf{F}_{ij} \) (\( t = 1, \ldots, T; j = 1, \ldots, T \)) are \( k_2 \times k_1 \) coefficient matrices, and \( B \) is a \( T \times (T + 1) \) coefficient matrix for the dependent variables. Also, \( \mathbf{v}_{0i}, \mathbf{v}_{1i}, \) and \( \mathbf{v}_{2it} \) (\( t = 1, \ldots, T \)) are vectors of errors. Each equation of the system (3.6)-(3.8) includes a constant term.

Equation(s) (3.6) is (are) the equation(s) of the initial condition(s). It (they) is (are) the unrestricted reduced form model(s) of the first observation(s) of the dependent variable in the sample specified as function(s) of the purely exogenous explanatory variables, \( \mathbf{x}_{1it} \). Equations (3.8) are a set of unrestricted reduced form models of the endogenous variables, \( \mathbf{x}_{2it} \), specified as functions of the purely exogenous variables, \( \mathbf{x}_{1it} \). Finally, system (3.7) is the simultaneous-equations variant of the dynamic error-component model which imposes cross-equation linear restrictions on the parameters of matrices \( \mathbf{C}_1, \mathbf{C}_2 \), and \( B \). Since the same set of explanatory variables appears in every equation of system (3.7), the restrictions amount to imposing the equality of the coefficients of each variable across all the equations as well as the equality of the intercepts of these equations. System (3.6)-(3.8) is identified if: i) \( k_1 \geq 1 \), ii) \( T \geq 4 \), and iii) \( \lim_{N \to \infty} (Z'Z/N) \) is positive definite where \( Z \) is the data.
matrix of the purely exogenous variables $x_{1,t}$ (Bhargava (1991)). Although the coefficient matrix of the dependent variable, $B$, is triangular the system that comprises equations (3.6) and (3.7) is not recursive since we have assumed a non-diagonal covariance matrix for the error terms of equations (3.7); namely the covariance matrix (3.5). Therefore, a full-information estimation procedure must be undertaken for the estimation of the whole system such as Three Stage Least Squares (3SLS) or Full Information Maximum Likelihood (FIML) method (Lahiri and Schmidt (1978)). Bhargava and Sargan (1983) suggest the estimation of system (3.6)-(3.8) by the FIML method after directly substituting the restrictions implied by (3.5) into the covariance matrix of the residuals. The restricted FIML method is efficient in comparison with the 3SLS that does not impose any restrictions on the covariance matrix. However, if the restrictions on the covariance matrix are not true, the FIML imposing wrong restrictions will in general be inconsistent while the 3SLS, because it does not impose any restrictions on the covariance matrix of the residuals, remains consistent and is efficient within the class of estimators that do not impose restrictions on the covariance matrix. Taking into account the above considerations we adopt the following estimation and testing procedure:

**First**, recalling model (3.4) we accept the properties of the individual-specific effects $\eta_i$ described earlier, namely that these variables are supposed to capture ability, habits and states of mind which change very sluggishly over time, and that they are distributed independently across individuals with constant variance.

**Second**, the transitory residuals $e_it$ will be white noise processes if the model is correctly specified. Usually, persistent shocks to the model that are not captured by the included explanatory variables are assumed to be captured by the residuals thereby rendering them autocorrelated. In addition, omitted variables also become part of the residuals and in this way also contribute to render the residuals autocorrelated. Here, in effect, we define a model to be correctly specified if its set of explanatory variables is complete in the sense that it contains all the relevant variables that at the same time are sufficient to capture the effect of persistent shocks as well.

**Third**, it follows that when the model is correctly specified, the structure of the covariance matrix of the residuals is given by expression (3.5). If the model is misspecified the covariance structure will be different from (3.5). Therefore, tests of model specification can be based on tests of the structure of the covariance matrix. Since the 3SLS method yields consistent residuals we can estimate the simultaneous equation form, (3.6)-(3.8), of model (3.4) by this method without imposing the covariance structure (3.5), and use the
consistent 3SLS residuals to test whether their covariance matrix conforms with the theoretical covariance matrix (3.5). The latter becomes thereby the maintained hypothesis. Any significant deviation between these two matrices would indicate model misspecification.

A convenient testing procedure for the present purpose is that based on Wald tests since in that case it is not necessary to estimate the model under the restrictions imposed by the hypothesis under testing. A Wald test is of the form:

\[ W = N f(\hat{\omega})^T (F V F')^{-1} f(\hat{\omega}) \overset{d}{\to} \chi^2_r, \]

(3.9)

where \( \hat{\omega} \) is a vector of the consistent estimates of the unique elements of the covariance matrix estimated from the 3SLS residuals\(^{15} \), \( f(\hat{\omega}) \) is a vector of \( r \) restrictions on the elements of \( \hat{\omega} \), \( F = \partial f(\hat{\omega}) / \partial \omega' \), and \( V \) is a consistent estimate of the covariance matrix of \( \hat{\omega} \)\(^{16} \). The derivation of the formula for this covariance matrix does not demand the assumption of normally distributed errors. The formula for the covariance matrix is shown in Appendix 3.B.

Inspection of the covariance matrix (3.5) reveals that the elements on the principal diagonal of this matrix are equal and the remaining elements are all equal to one another. Hence, the Wald test of the null hypothesis that the error-component model is correctly specified, amounts to testing these two properties of the covariance matrix. Under the null hypothesis, the Wald statistic is distributed as a Chi-square variable with \( T(T+1)/2 - 2 \) degrees of freedom. Since equations (3.6) and (3.8) of the system (3.6)-(3.8) are just the equations for the initial conditions and the instrumentation of the endogenous variables, the Wald test should ignore their error terms and, thus, consider only the error term of the system (3.7). Therefore, in the expression for the calculation of the degrees of freedom mentioned above, \( T \) equals the number of equations in system (3.7).

---

\(^{15} \) Since the covariance matrix of the residuals is symmetric we need only consider the elements in its upper or lower triangle. From now on we will consider only the elements in the upper triangle of this matrix. Hence, vector \( \omega \) is obtained by stacking rows in the upper triangle of the residuals' covariance matrix. The dimension of \( \omega \) is \( T(T+1)/2 \).

\(^{16} \) The elements in \( V \) are properly arranged to correspond to the elements in \( \omega \).
If the error-component model is misspecified, then the transitory component of its error term, $\epsilon_{it}$, is likely to be autocorrelated. Representing this autocorrelation by an autoregressive model of order $p$, $(\text{AR}(p))$, the error term of the random effects model should read:

$$v_{it} = \eta_{i} + \epsilon_{it}$$

$$\epsilon_{it} = \sum_{j=1}^{p} \rho_{j} \epsilon_{i,t-j} + w_{it}, \quad (3.10)$$

where the coefficients of the autoregressive process are assumed to satisfy the conditions for stationarity, and $w_{it}$ is an independent and identically distributed error process. The covariance matrix of the error term specified as in (3.10) is now given by:

$$\text{Var}(v_{i}, v_{i}') = E(v_{i}v_{i}') = \sigma_{\epsilon}^{2} \Phi + \sigma_{\alpha}^{2} \sigma_{\epsilon}^{2}, \quad (3.11)$$

where $\Phi$ is a $T \times T$ matrix with elements of the form:

$$\tilde{\omega}_{ts} = \begin{cases} 1 & \text{if } t = s \\ \phi_{|t-s|} & \text{if } t \neq s, \end{cases} \quad (3.12)$$

which are autocorrelation coefficients at lags indicated by the subscript.

The formulae of the autocorrelation coefficients (3.12) will differ depending on the degree $p$ of the autoregressive process. However, irrespective of what this degree is, the covariance matrix (3.11) will exhibit the property that its elements on each diagonal will be equal to one another and unequal to the elements on any other diagonal.

If the transitory component follows a moving-average process of order $q$, $(\text{MA}(q))$, then the covariance matrix of the random effects model will have a structure similar to that of matrix (3.11) with the difference that only the elements along the principal diagonal and the first $q$ off-diagonals will be equal to one another and unequal to the elements on different diagonals.
### Table 3.A.1: Descriptive Statistics of Variables

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<tr>
<th>Variable</th>
<th>Mean</th>
<th>Std</th>
<th>Min</th>
<th>Max</th>
<th>Units</th>
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<tr>
<td>PM</td>
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<td>15.64</td>
<td>83.42</td>
<td>152.15</td>
<td>1982 = 100</td>
</tr>
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<td>PL</td>
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<td>34.98</td>
<td>317.35</td>
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<td>66.51</td>
<td>35.54</td>
<td>1214.86</td>
<td>1982 = 100</td>
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<td>1982 = 100</td>
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<td>773.30</td>
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<td>24.90</td>
<td>833.00</td>
<td>SEK</td>
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<tr>
<td>w</td>
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<td>222.05</td>
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<tr>
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<td>12.09</td>
<td>75.27</td>
<td>152.05</td>
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<tr>
<td>Q</td>
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<td>1373.25</td>
<td>31.36</td>
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<td>Million SEK</td>
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<td>35.19</td>
<td>10761.52</td>
<td>Million SEK</td>
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(Table 3.A.1 continues)
(Table 3.A.1 concluded)

<p>| | | | | | |</p>
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<td>-59.57</td>
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<tr>
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<td>2824.00</td>
<td>47.00</td>
<td>21828.00</td>
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</tr>
<tr>
<td>VA_H</td>
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<td>-652.23</td>
<td>1726.37</td>
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<tr>
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<td>623.97</td>
<td>-862.98</td>
<td>7024.96</td>
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</tr>
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<td>633.44</td>
<td>-909.49</td>
<td>8192.12</td>
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</tr>
<tr>
<td>K</td>
<td>843.82</td>
<td>1814.11</td>
<td>0.73</td>
<td>14464.57</td>
<td></td>
</tr>
<tr>
<td>CU</td>
<td>87.30</td>
<td>12.20</td>
<td>25.00</td>
<td>100.00</td>
<td></td>
</tr>
</tbody>
</table>

Points in %
Appendix 3.B

The asymptotic variance-covariance matrix of the 3SLS residuals has been derived by Bhargava (1987) and is given below.

\[
V = S' \begin{bmatrix}
D_4 + (I + \Pi)(I_T \otimes \Omega B^{-1}) \left( \frac{\partial \text{vec} B}{\partial \theta} \right) \text{Var}(\theta) \left( \frac{\partial \text{vec} B}{\partial \theta} \right) & \\
- (I + \Pi)(I_T \otimes \Omega B^{-1}) \left( \frac{\partial \text{vec} B}{\partial \theta} \right) \text{Var}(\theta) \left( \frac{\partial \text{vec} A}{\partial \theta} \right) & \\
D_3 (I_T \otimes \Omega^{-1} Q) \left( \frac{\partial \text{vec} A}{\partial \theta} \right) \text{Var}(\theta) \left( \frac{\partial \text{vec} B}{\partial \theta} \right) & \\
- D_3 (I_T \otimes \Omega^{-1} Q) \left( \frac{\partial \text{vec} A}{\partial \theta} \right) \text{Var}(\theta) \left( \frac{\partial \text{vec} B}{\partial \theta} \right) & \\
\end{bmatrix} S'.
\]

In the formula above, vec is the usual function that stacks the rows of a matrix, S is a selection matrix that selects the unique elements in the upper triangle of a matrix, \(\Pi\) is the permutation matrix which for an arbitrary square matrix \(F\) is such that \(\Pi \text{vec}(F) = \text{vec}(F')\), \(B\) is the coefficient matrix of the dependent variable, \(A = (B : C)\), \(\theta_B\) and \(\theta\) are, respectively, the unrestricted elements of \(B\) and \(A\), while \(\text{Var}(\theta_B)\) and \(\text{Var}(\theta)\) are the respective covariance matrices. Vector \(\bar{z}\) comprises the mean values of the explanatory variables and \(Q' = (P : I_k)\) where \(P = -B^{-1}C\) and \(k = k_1 + k_2\). Finally, \(\Omega\) is the covariance matrix of 3SLS residuals, and \(D_3, D_4\) are, respectively, the matrices of the third and fourth moments of the residuals.
Chapter 4

Expectations Formation Mechanisms

4.1 Introduction

The shift of interest from static analyses of individual optimising behaviour to dynamic analyses in the early 1960s has brought with it an increased interest in expectations formation mechanisms. The reason is that agents' decision rules derived from a dynamic behavioural framework are inherently forward-looking processes (Eisner and Strotz (1963), Lucas (1967), Gould (1968)). The implication of this is that agents' decisions at each time period are based on their expectations/plans of the entire future time paths of the exogenous variables. Although intuitively appealing, dynamic decision rules defy direct empirical implementation since data on expectations formed at a particular date for several future dates are not generally available. A way out of this impasse is to incorporate agents' expectations formation mechanisms in the decision rules and let them generate the expectations/plans of future values. Since these mechanisms are functions of past expectations and realisations, decision rules become susceptible to empirical analysis.

Theory provides no information about the specification of the expectations formation mechanisms and therefore we hope for possible evidence offered by the data. A prerequisite for any progress in this kind of empirical analyses is the availability of direct measures of expectations/plans. During the last decades and in a large number of countries, data have been collected from individual firms on expectations and plans for a variety of variables. Most of these data are categorical, i.e. respondents are asked whether they expect the values of particular variables to increase, decrease or remain at the same level over a specified future period. A disadvantage with this kind of data is that to become operational,
they have to be converted into quantitative data; a procedure that may introduce substantial measurement errors into the measures of expectations. This kind of errors are avoided if direct quantitative measures of expectations are available\footnote{For a survey of studies on expectations formation processes see Pesaran (1987). A description and evaluation of different conversion techniques is given in Nerlove (1983) and Pesaran (1985).}

In this chapter we implement empirically different models of expectations formation utilizing the quantitative data on expectations and plans of Swedish manufacturing firms from the survey conducted by IUI. Most of the studies on firms’ formation of expectations have been carried out on aggregate data constructed by aggregating over individual expectations provided by surveys. In contrast, the present analysis is conducted at the disaggregate level. Firms’ expectations as to two variables are investigated: the hourly labour cost and the level of output. We consider two broad classes of expectations formation models. The first class comprises some of the most frequently used purely extrapolative models such as partial adjustment and error-correction models. The set of explanatory variables in this class is confined to include past expectations and realisations only. The second class comprises models that augment the purely extrapolative mechanisms by allowing some additional variables to exert an independent effect on current expectations formation.

The purpose of the chapter is threefold. First, empirical evidence for the correct functional form of the expectations formation processes is sought in the prospect of the derivation of a closed-form investment demand function in the next chapter. Second, the empirical analysis is expected to reveal the performance of some of the most frequently used expectations formation processes at the disaggregate level. Third, the data is expected to provide evidence on whether any additional variables have an independent effect on expectations formation.

The disposition of the chapter is as follows. In Section 4.2 we provide a description of different expectations models and discuss their optimality properties. Section 4.3 contains the empirical implementation of these models. Four models from the class of purely extrapolative and one model from the class of augmented extrapolative models are estimated for each of the two variables. Finally, Section 4.4 contains the summary of the chapter.
4.2 Specification of the Expectations Formation Mechanism

Models from the class of purely extrapolative mechanisms are members of the following general specification:

\[ Y^e_{t+1} = \alpha + \sum_{i=0}^{n} \beta_i Y^e_{t-i} + \sum_{i=0}^{m} \gamma_i Y^r_{t-i} + \epsilon_t, \]  

where \( Y^e_{t+1} \) is the expected value of the variable \( Y \) at time \( t \) for \( t+1 \), \( Y^e_{t-i} \) are lagged expected values of \( Y \), \( i = 0,1,2,...,n \), and \( Y^r_{t-i} \), \( i = 0,1,2,...,m \), are the realised values of \( Y \) (the underlying variable). The error process \( \epsilon_t \) is assumed to be independently and identically distributed, the coefficients \( \alpha, \beta \), and \( \gamma \) are assumed to be constant and we will also assume that the coefficients \( \beta \) satisfy the necessary conditions for stationarity.

Several broadly used expectations adjustment models can be obtained from (4.1) by imposing appropriate restrictions on its coefficients. By far the most popular one is the first-order adaptive model (also called the partial adjustment model) which postulates that agents adjust their expectations proportionally to the latest discrepancy between expected and realised value of the underlying variable (Koyck (1954)):

\[ Y^e_{t+1} - Y^e_t = \theta(Y_t - Y^e_t) + \epsilon_t. \]  

The magnitude of the adjustment of expectations is determined by the coefficient \( \theta \), assumed to lie in the range \( 0 < \theta < 2 \). The higher the value of \( \theta \) the more rapid the adjustment of expectations.

---

18 These models can also be derived as special cases of the general distributed lag specification:

\[ Y^e_{t+1} = W(L)Y_t, \]  

by the imposition of suitable restrictions on the shape of the lag operator \( W(L) \). Expression (*) is a more convenient specification in two particular cases. First, when one wants to assess the optimality property of the adjustment mechanisms: if the process that drives the underlying variable coincides with specification (*) then the corresponding adjustment mechanism is optimal. Second, if one has chosen an adjustment mechanism, i.e. the form of \( W(L) \) is known and wants to make forecasts for several periods in the future, (*) is a more convenient device compared to (4.1). This second case is of interest in the derivation of the investment function in the next chapter.
As pointed out in the literature, the simple adaptive model (4.2) suffers from some important drawbacks. First, it does not allow short-term effects (such as current changes in the underlying variable) on the adjustment of expectations. It rather maintains that the latter is only driven by the current disequilibrium \((Y_t - Y^*_t)\) which is to be interpreted as a long-term effect. Second, expectations adjusted according to (4.2) are optimal only if the underlying variable has an autoregressive moving average representation ARIMA(0,1,1), e.g., \(Y_t\) follows a random walk process with a moving average error. It is well-known, however, that the forecasts for all lead times of a variable following an ARIMA(0,1,1) process are simply equal to the latest realisation of that process. Thus, the adjustment rule (4.2) is optimal only if agents believe that economic variables will remain at the current level for the entire future, i.e. agents expectations are stationary. This is hardly a realistic assumption and therefore model (4.2) could not be considered as a meaningful behavioural representation\(^{19}\).

The first-order adaptive model can be readily generalized by including second- or higher-order error-correction terms in (4.2). Hence, the \(r\)th-order adaptive model may be written as:

\[
Y^s_{t+1} - Y^s_t = \sum_{i=0}^{r} \theta_i (Y_{t-i} - Y^s_{t-i}) + u_t. \tag{4.3}
\]

Frenkel (1975) derives an expectations adjustment process by distinguishing between the determination of the short-term and the long-term expectations. He assumes that long-term expectations adjust slowly according to the first-order adaptive mechanism (4.2):

\[
Y^n_{t+1} - Y^n_t = \theta (Y_t - Y^n_t) \quad 0 < \theta < 2, \tag{4.4}
\]

where \(Y^n\) stands for the normal or average level of \(Y\).

Short-term expectations are, in turn, adjusted according to the following rule:

\[19\] A third disadvantage with the adjustment rule (4.2) is that it does not allow for a time trend in the underlying variable although many economic variables exhibit such a trend. Yet, the predictive ability of (4.2) was considered as satisfying until the mid 1970s. An explanation for that can be found in the fact that (4.2) is usually complemented with an intercept. Now, it so happens that in an environment of constant growth, the rate of growth of the underlying variable appears as a constant intercept in (4.2) hence improving its fit (Pagan (1985)). It was during the volatile 1970s that its adequacy was questioned.
Expression (4.5) postulates that current expectations adjust in accordance to the deviations of the realised values of the underlying variable from the short-term and the long-term expectations.

From expression (4.4) we have that:

\[ Y_t^n = \frac{\theta}{1 - (1 - \theta)L} Y_{t-1}, \quad (4.6) \]

where \( L \) is the lag operator defined as \( L^i x_t = x_{t-i} \). Substituting this result into (4.5) we obtain the following short-term expectations adjustment model:

\[ Y_{t+1}^e - Y_t^e = \gamma_1 (Y_t^e - Y_t^n) + \frac{\gamma_2 (1 - L)}{1 - (1 - \theta)L} Y_t, \quad (4.7) \]

which can also be written in the following form:

\[ Y_{t+1}^e - Y_t^e = (1 - \theta - \gamma_1) (Y_t^e - Y_{t-1}^e) + \theta \gamma_1 (Y_{t-1}^e - Y_{t-1}^e) + (\gamma_1 + \gamma_2) (Y_t - Y_t^n). \quad (4.8) \]

The expectations adjustment rule (4.8) is an error-correction model which postulates that agents change their expectations in response to current changes in realisations \((Y_t - Y_{t-1})\) (the coefficient \((\gamma_1 + \gamma_2)\) being the short-term effect), the previous expectations error \((Y_{t-1}^e - Y_{t-1}^e)\) (the coefficient \(\theta \gamma_1\) reflecting the long-term effect), and the latest change in expectations \((Y_t^e - Y_{t-1}^e)\).

In order to find the specific process of the underlying variable for which the adjustment rule (4.8) is optimal, it is instructive to rewrite it in a general distributed lag specification:

\[ Y_{t+1}^e = \frac{(\gamma_1 + \gamma_2) - (\gamma_1 + \gamma_2 - \theta \gamma_1) L}{[1 - (1 - \theta) L][1 - (1 - \gamma_1)L]} Y_t, \]

\[ = \frac{(\gamma_1 + \gamma_2) \Delta Y_t + \theta \gamma_1 Y_{t-1}}{[1 - (1 - \theta) L][1 - (1 - \gamma_1)L]}. \quad (4.9) \]
We are looking for an ARIMA process the one-period-ahead forecasts of which are
given by (4.9). We managed to find an approximation only: the ARIMA(1,1,1) process.
This process can be written as:
\[
\Delta Y_{t+1} = \alpha \Delta Y_t + \epsilon_{t+1} - \delta \epsilon_t. \tag{4.10}
\]
The optimal forecast of \(\Delta Y_{t+1}\), which we denote by \(\Delta \hat{Y}_{t+1}\), is:
\[
\Delta \hat{Y}_{t+1} = E(\Delta Y_{t+1} | \Delta Y_t, \Delta Y_{t-1}, \ldots) = \alpha \Delta Y_t - \delta \epsilon_t, \tag{4.11}
\]
where \(E(\Delta Y_{t+1} | \Delta Y_t, \Delta Y_{t-1}, \ldots)\) is the conditional mathematical expectations operator.
Now, using (4.10) we have:
\[
\epsilon_t = \frac{1}{(1 - \delta L)^{-1}} \left(\Delta Y_t - \alpha \Delta Y_{t-1}\right). \tag{4.12}
\]
Inserting this result into expression (4.11) yields:
\[
\Delta \hat{Y}_{t+1} = \frac{\alpha \Delta Y_t - \delta(1 - \delta L)^{-1}(1 - \alpha L)\Delta Y_t}{1 - \delta L}, \tag{4.13}
\]
Noticing that (4.13) is in first differences, and thus a term \((1-L)\) has been moved to
the left-hand side of the equation, expression (4.13) is an approximation of (4.9) under the
condition that one of the coefficients \(\theta\) or \(\gamma\) in (4.9) is small.
The simple acceleration model is also a member of (4.1) and is written as:
\[
Y^\delta_{t+1} - Y^\delta_t = \delta(Y_t - Y_{t-1}) + u_t. \tag{4.14}
\]
The adjustment rule (4.14) postulates that expectations should be revised only if the
rate of the underlying variable in the current period has been accelerating or decelerating.
Hence, this adjustment rule allows only for short-term effects and, contrary to the simple
adaptive model (4.2), it ignores long-term effects altogether. Optimality of (4.14) requires
that \(Y_t\) is driven by an ARIMA(1,0,0) process which is a stationary process. It is well-known,
however, that typical economic variables are non-stationary and, as it is reasonable to assume that economic agents are aware of that, we would not expect to observe the adjustment rule described by (4.14).

Similarly with the simple adaptive model, the acceleration model can be generalised in a straight-forward manner. The \( r \)th-order acceleration model may be written as:

\[
Y_{t+1} - Y_t = \sum_{i=0}^{r} \delta_i (Y_{t-i} - Y_{t-1-i}) + u_t, \tag{4.15}
\]

Specification (4.1), and the models that it comprises, is relatively limited in scope since it ignores the independent effect on expectations of variables other than the past history of expectations and realisations of the underlying variable (Pesaran (1985,1987)). Indeed, at the time expectations are formed, agents have at their disposal a great amount of information that could improve the accuracy of their forecasts if it was taken into account. Moreover, since the cost of this additional information is often low (e.g., information internal to the firms or published by Statistical Bureaus) it is reasonable to assume that economic agents make regular use of such information. We can thus extend model (4.1) by allowing expectations to depend on a set of additional factors, represented by the column vector \( x_t \):

\[
Y_{t+1} = \alpha + \sum_{i=0}^{m} \beta_i Y_{t-i} + \sum_{i=0}^{m} \gamma_i Y_{t-i} + \sum_{i=0}^{k} \alpha_i x_{t-i} + \epsilon_t, \tag{4.16}
\]

where the sequence of column vectors \( x_{t-i}, i=0,1,2,...,k \), indicates that both current and past values of \( x \) influence current expectations.

The issue of choosing a particular model out of the class of models (4.16) is more involved than choosing a model out of the class of purely extrapolative models. The reason for that obviously arises from the fact that one must choose the variables that will be included in vector \( x \). Putting expression (4.16) within the context of a well-articulated economic theory could provide us with a set of potential candidate variables for the vector \( x \). The final specification of the expectations formation process, however, will depend on our assumption about the degree of agents' understanding of the functioning of the economic system and the way this system affects them. In other words we need an assumption on the degree of rationality in the behaviour of economic agents. Within the Rational Expectations Hypothesis (R.E.H.) doctrine, due to Muth (1961), agents'
behaviour is perfectly rational. The R.E.H. implies that expectations are formed in accordance with the true process that drives the variable as to which expectations are formed. The expectations formation mechanism will, therefore, coincide with the reduced-form model of the underlying variable derived from the true structural system that describes the economy. This is admittedly rather an extreme hypothesis. What seems more reasonable is to assume bounded rationality in the behaviour of economic agents by allowing the incorporation of a limited number of variables in vector $\chi$ that are likely to exert an independent effect on the formation of expectations.

4.3 Empirical Implementation

In this section we estimate and test expectations formation processes from the two classes of models presented in the previous section. We focus on the formation of expectations of Swedish manufacturing firms as to their labour cost $W$, and production volume $Q$. The variable labour cost is defined here as nominal hourly wage cost including employers' contribution to social security, while production volume is measured as output at constant prices. Descriptive statistics of the two variables (both expected and realised) are shown in Appendix 3.A to Chapter 3. The same chapter also describes the econometric methodology on which the present empirical analysis is based. For ease of presentation we first consider the purely extrapolative models and then the augmented extrapolative models.

4.3.1 Purely Extrapolative Models

We choose four models from the first class: the first- and second-order adaptive model (denoted as $M_1$ and $M_2$, respectively), the Frenkel's error-correction model ($M_3$), and the simple acceleration model ($M_4$). We collect them here:

$$M_1: \quad Y_{i,t+1}^e - Y_{it}^e = \theta_0 + \theta_1(Y_{it} - Y_{it}^e) + v_{it} \quad (4.17)$$

$$M_2: \quad Y_{i,t+1}^e - Y_{it}^e = \theta_0 + \theta_1(Y_{it} - Y_{it}^e) + \theta_2(Y_{i,t-1} - Y_{i,t-1}^e) + v_{it} \quad (4.18)$$
\[ M3: \quad Y_{i,t+1}^e - Y_{i,t}^e = \gamma_0 + \gamma_1(Y_{i,t}^e - Y_{i,t-1}^e) + \gamma_2(Y_{i,t-1} - Y_{i,t-1}^e) + \gamma_3(Y_{i,t}^e - Y_{i,t-1}^e) + \nu_{i,t} \quad (4.19) \]

\[ M4: \quad Y_{i,t+1}^e - Y_{i,t}^e = \delta_0 + \delta(Y_{i,t}^e - Y_{i,t-1}^e) + \nu_{i,t} \quad (4.20) \]

where \( Y = l', Q \) and

\[ \nu_{i,t} = \eta_{i,t} + \varepsilon_{i,t}, \quad i = 1, \ldots, N, \quad t = 1, \ldots, T, \]

where the error component \( \eta_{i,t} \) represents the firm-specific effect and \( \varepsilon_{i,t} \) is the transitory component of the error term. According to our maintained hypothesis the effects \( \eta_{i,t} \) have zero means and constant variance \( \sigma^2_{\eta} \), while correct model specification implies that the terms \( \varepsilon_{i,t} \) will have zero means and constant variance \( \sigma^2_{\varepsilon} \).

All models except M3 are static in the sense that they do not include lagged dependent variables among the explanatory variables. Thus, only model M3 needs the initial conditions equation (3.6) of the simultaneous equation system (3.6)-(3.8) (see Chapter 3). Explanatory variables including parts of current or lagged dependent variables are contemporaneously correlated with the error terms and, therefore, must be instrumented in order to retain consistency in the parameter estimates. The correlation arises from the temporal dependence of the error terms which stems from the maintained hypothesis that the time invariant individual-specific effects are part of the error terms. The instrumentation of the endogenous variables can be facilitated by equations (3.8) of system (3.6)-(3.8)\(^{20}\). As explanatory variables in these equations we have used the realised values of the underlying variables (i.e. \( l'_{it} \) and \( Q_{it} \) respectively), differenced once, over the whole sample period. Although one could conceive of other instruments, these variables turned out to provide relatively high fit.

---

\(^{20}\) It should be noticed that equations (3.8) are not intended, in the first place, to facilitate instrumentations of this kind of endogeneity. Rather, they are intended to facilitate the removal of the correlation between the individual-specific effects in the error term and some of, otherwise, exogenous variables that usually arises in empirical analyses at the disaggregate level. Expectational variables belong to this class of variables (see the methodological discussion in Chapter 3, and the models in the next subsection and in the next chapter).
Data over the period 1982-1988 were available. As the dependent variables are in first differences there were six observations per firm left for the estimation of models M1 and M4 and five observations for models M2 and M3. The last two models need one additional lagged value of the explanatory variables. Since there was an additional observation available on the realised values one period prior to the beginning of the sample, model M4 could be estimated on six observations.

When estimating model M1, system (3.7)-(3.8) comprised twelve equations: six equations in (3.7), one for each time period, and six equations in (3.8) one for each endogenous variable. For model M2, the number of equations in (3.7) reduces to five, while system (3.8) consisted of six equations. The latter follows from the fact that the second endogenous variable in M2 is just the lag of the first endogenous variable. The initial conditions equation (3.6) was used when model M3 was estimated, while systems (3.7) and (3.8) for this model consisted of five equations each. Finally, for the estimation of model M4, six equations were used, all in system (3.7).

Since the estimation of each model has demanded a different amount of equations in the simultaneous equation system (3.6)-(3.8), one should be careful in interpreting the values of the $R^2$ statistic. As a matter of fact, the $R^2$ statistics from the four models are not directly comparable. Rather, they depend to a certain extent on the amount and the fit of the equations in parts (3.6) and (3.8) of the system (3.6)-(3.8). The more variables that must be instrumented and the higher the fit of the instruments, the higher the value of the $R^2$ statistic for the whole system. Furthermore, the longer lags in a model, the fewer observations on which the estimation is conducted. Since, as known, $R^2$ values are inflated by the time trends of the variables, in a typical panel data analysis with a few observations, a forgone observation due to an additional lagged variable will obviously have a negative effect on the value of the $R^2$ statistic. Thus, e.g. the fit of model M3 as measured by $R^2$ is not directly comparable to that of, say, model M4.

We now turn to the results from the estimation and testing of the models that are shown in Tables 4.1 and 4.2 for the labour cost expectations and output plans respectively. In general, all the models performed well in terms of parameter significance and expected parameter sign. Except for variable $\left( W_{t-1} - W_{t-1} \right)$ in model M3 for the labour cost and the constant term in model M4 for the output level, all other coefficients turned out to be significant (the two variables were however significant at the 10 per cent level). The estimates of current unfulfilled expectations/plans $\left( Y_a - Y_a^* \right)$, $Y = W, Q$, turned out to be strong and positive indicating a quick adjustment of expectations/plans towards current
Table 4.1
Estimates of Wage Costs Expectations, Purely Extrapolative Models
M1-M4
(Time Period: 1982-1988, Number of Firms in the Sample: 93)

Dependent Variable: $W_{i,t+1}^* - W_{it}^*$

<table>
<thead>
<tr>
<th>Models</th>
<th>M1</th>
<th>M2</th>
<th>M3</th>
<th>M4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Explanatory Variables</strong></td>
<td><strong>Constant</strong></td>
<td>$W_{it} - W_{it-1}^*$</td>
<td>$W_{it} - W_{it}^*$</td>
<td>$W_{it}^* - W_{it-1}^*$</td>
</tr>
<tr>
<td></td>
<td>7.05 (10.46)</td>
<td>9.27 (11.69)</td>
<td>2.66 (4.54)</td>
<td>4.44 (7.95)</td>
</tr>
<tr>
<td></td>
<td>0.90 (12.80)</td>
<td>0.74 (8.97)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>-0.46 (-5.21)</td>
<td>-0.15 (-1.31)</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>-</td>
<td>-0.25 (-2.21)</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>-</td>
<td>0.81 (8.09)</td>
<td>0.49 (10.80)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Instruments (s = 1982-1988)</th>
<th>$R^2$</th>
<th>Wald test</th>
<th>$T^*$</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.47</td>
<td>28.76</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>0.35</td>
<td>20.43</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>0.93</td>
<td>15.80</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>0.15</td>
<td>43.59</td>
<td>6</td>
</tr>
</tbody>
</table>

Notes: i) t-values in parentheses.
   ii) The Instruments in the last column are the explanatory variables in equations (3.8). The Initial Value Instruments are the explanatory variables in equation (3.6).
   iii) Statistic $R^2$ is a system statistic and therefore affected by the number of equations in system (3.7) as well as by the number and fit of equations in systems (3.6) and (3.8) (see the comments in the text).

(Table 4.1 continues)
iv) \( T\) is the number of equations (i.e. number of time periods) in system (3.7). Since models M1-M4 are in differences, \( T\) equals \( T-1\). In addition, the higher the order of lagged explanatory variables the fewer the equations as in models M2 and M3.

v) The Wald statistics concern the test of the null hypothesis of correct model specification. For the random effects model this amounts to testing that the elements on the principal diagonal of the covariance matrix of system (3.7) are equal and the remaining elements are all equal to one another. The Wald statistics are distributed asymptotically as \( \chi^2 \), where the number of restrictions, \( r\), equals \( T*(T* + 1)/2 - 2\).

realisations. In output level models in particular, firms seem to adjust immediately their production plans to current realised levels and, according to model M1, to levels even higher than that. Strong and positive was also the parameter estimate of the current change in the underlying variable, \( Y_{it} - Y_{it-1} \), except for model M4 for the wage cost. This again indicates a quick adjustment in the right direction, since the sign of the estimate implies that expectations are adjusted upwards (downwards) when the rate of \( Y_u \) in the current period has been accelerating (decelerating). An overreaction of firms' output plans can be noticed here too, by means of the estimate in model M3 which is greater than one. The estimates of the lagged dependent variables in models M3, \( Y_{it} - Y_{it-1} \), were less than one in absolute value implying that the expectations/plans adjustment processes are stable. Finally, the lagged expectations/plans errors turned out to have different effects in different models: among the output level models, it was very low and negative in model M2 while it was high and positive in model M3. Among the wage cost models, it turned out to be negative and of moderate magnitude in M2 while it was insignificant in model M3.

The Wald statistics reported in the two tables concern the test of the null hypothesis of correct model specification. As it was pointed out in Chapter 3, correct specification of the random effects model implies that the elements on the principal diagonal of the covariance matrix of system (3.7) are equal and the remaining elements are all equal to one another (see expression (3.5)). Under the null, the Wald statistics are distributed as \( \chi^2 \) variables where the number of restrictions \( r\) equals \( T*(T* + 1)/2 - 2\) with \( T*\) equal to the number of equations in system (3.7). The relevant critical values of the tests at the 5 per cent significance level are 30.14 and 22.36 for \( T* = 6\) and \( T* = 5\), respectively. The null hypothesis is rejected for model M4 both in the case of labour cost expectations and output plans. Hence, the data does not support the specification of this model and provides evi-

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The null hypothesis is not rejected, however, for any of the other three models and for both variables. In the light of the good performance of all models, this is an undesirable outcome as the selection of the preferred model out of the three now becomes difficult. We will, however, attempt an evaluation of the models in terms of their $R^2$ values.

Ranking the models M1-M3 according to their model fit gives a precedence to Frenkel's error-correction model. Its $R^2$ value is equal to 0.93 for both the wage cost and the output level equations. As we mentioned earlier the value of the $R^2$ statistic probably increases with the number of endogenous explanatory variables that must be instrumented and the presence of an initial conditions equation. Hence, Frenkel's models having one endogenous explanatory variable and an initial conditions equation are not directly comparable with models M1, in terms of the $R^2$ statistic, as the latter have only one endogenous variable and are static. Nevertheless, the differences in the $R^2$ values for the whole systems are rather large providing a certain advantage to Frenkel's model. With respect to model M2 we notice that this model is in a favourable position since they have two endogenous variables, yet their $R^2$ values are lower than those of the M3 models. Comparison of the $R^2$ values of the models in Table 4.1 and 4.2 reveals that the superiority of Frenkel's model is more notable in the case of labour cost expectations than in the case of output plans.

It might be of interest to speculate on the reasons why the Wald test could not discriminate among the first three expectations models. Looking closer to the regressors of these models one can notice that they are all specified either as changes in variables or as differences between two variables with, probably, similar trends. One could hence expect that the regressors are trendless, a fact that makes difficult for diagnostic tests, such as the Wald test, to detect the omitted variables and thus to discriminate among competing models so similar as the three models considered here.

In summary, the four purely extrapolative models performed well in terms of parameter significance. However, selecting the best model from this class turned out to be difficult as the utilised Wald test of model specification provided support for three of the four models. Nevertheless, besides its theoretical appeal, Frenkel's model was superior in

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21 Notice that the presence of autocorrelation in the transitory component of the error term does not render the parameter estimates of the models inconsistent. This is because the models have been estimated by the 3SLS method and therefore corrected for an unrestricted form of autocorrelation in the residuals at the second stage.
<table>
<thead>
<tr>
<th>Models</th>
<th>M1</th>
<th>M2</th>
<th>M3</th>
<th>M4</th>
<th>Instruments (s = 1982-1988)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>20965 (4.47)</td>
<td>26566 (5.86)</td>
<td>21375 (6.53)</td>
<td>4332 (1.48)</td>
<td>-</td>
</tr>
<tr>
<td>$Q_u - Q^*_u$</td>
<td>1.07 (47.78)</td>
<td>0.99 (37.20)</td>
<td>-</td>
<td>-</td>
<td>$(Q_{is} - Q_{i,s-1})$</td>
</tr>
<tr>
<td>$Q_{i,t-1} - Q^*_i,t-1$</td>
<td>-</td>
<td>-0.084 (-3.07)</td>
<td>0.76 (18.55)</td>
<td>-</td>
<td>$(Q_{is} - Q_{i,s-1})$</td>
</tr>
<tr>
<td>$Q^<em>_u - Q^</em>_i,t-1$</td>
<td>-</td>
<td>-</td>
<td>-0.73 (-21.30)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>$Q_u - Q^*_i,t-1$</td>
<td>-</td>
<td>-</td>
<td>1.05 (37.29)</td>
<td>0.70 (33.95)</td>
<td>-</td>
</tr>
</tbody>
</table>

| $R^2$ | 0.84 | 0.89 | 0.93 | 0.59 |
| Wald test | 22.40 | 14.00 | 17.12 | 38.20 |
| $T^*$ | 6 | 5 | 5 | 6 |

Initial Value Instruments (s = 1982-1988) | - | - | $(Q_{is} - Q_{i,s-1})$ | - |

Notes: See the notes of Table 4.1.

terms of $R^2$ values. The inability of the Wald test to discriminate among different models raised doubt on its ability to detect omitted variables in general. Although one might suspect that this is the result of lack of trends in variables in first differences, the question
is posed as to whether the correct expectations formation mechanism is a member of the
class of purely extrapolative models. Therefore, we now turn to the class of augmented
extrapolative models.

4.3.2 Augmented Extrapolative Models

The determination of the set of variables in vector $x$ of the augmented models (4.6)
will be based on the assumption that economic agents are boundedly rational. The
implication of this assumption is that the information sets used by the agents, without being
complete, contain additional variables representing readily available information that can
improve their forecasts. In the literature of wage cost determination interest has been
focused on two particular issues. First, the conditions in the labour market, and second
the profit-generating ability of the firm. As an indicator of labour market conditions, the
rate of unfilled vacancies has seemed to perform well and better than the rate of unem­
ployment. The choice of unfilled vacancies variable is in line with traditional economic
theory that excess demand for labour will drive the wage rate up. On the other hand, the
higher the profits of the firms the higher their propensity to increase the reward to the
production factors. Hence, the value added variable has been considered as an appropriate
candidate for the wage cost equation. Producer price indices have also turned out to be
significant probably because output price is part of value added. On the contrary, increases
in consumer prices have typically given less satisfactory results (Schager (1988)). In
specifying the augmented extrapolative model of the wage cost we will consider the effect
of value added and unfilled vacancies on the formation of expectations as to the wage cost.

The results from the estimation and testing of the labour cost equation are shown in
Table 4.3. Variable $VA_{H_i}$ is the realised value added per working hour constructed as
value added in current prices divided by total working hours, while variable $UNVAC$ equals
unfilled vacancies in per cent of employment constructed as the difference between current
planned and actual employment divided by current actual employment, multiplied by one
hundred. Descriptive statistics of the variables are given in Appendix A of Chapter 3. We
let current and lagged values of realised wage cost ($w_a$ and $w_{i-1}^a$), value added per hour
($VA_{H_i}$ and $VA_{H_{i-1}}$), and unfilled vacancies ($UNVAC_a$ and $UNVAC_{i-1}$) to enter
the set of explanatory variables. The two realised wage cost variables are intended to
capture the effect of the own past history of the underlying variable on the formation of
expectations in the current period.

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Table 4.3
Estimates of Wage Costs Expectations, Augmented Extrapolative Model
(Time Period: 1982-1988, Number of Firms in the Sample: 93)

<table>
<thead>
<tr>
<th>Explanatory Variables</th>
<th>M5</th>
<th>Instruments (s = 1982-1988)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>-6.07</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(-5.568)</td>
<td></td>
</tr>
<tr>
<td>$W_{i,t-1}$</td>
<td>0.99</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(23.511)</td>
<td></td>
</tr>
<tr>
<td>$W_{i,t-1}$</td>
<td>0.12</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(2.745)</td>
<td></td>
</tr>
<tr>
<td>$V A_H_{i,t-1}$</td>
<td>0.012</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(2.303)</td>
<td></td>
</tr>
<tr>
<td>$V A_H_{i,t-1}$</td>
<td>-0.001</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(-0.257)</td>
<td></td>
</tr>
<tr>
<td>$UNVAC_{i,t}$</td>
<td>0.21</td>
<td>$\Delta Q_{i,t}/Q_{i,t-1}$, $\Delta W_{i,t}/W_{i,t-1}$</td>
</tr>
<tr>
<td></td>
<td>(1.886)</td>
<td></td>
</tr>
<tr>
<td>$UNVAC_{i,t-1}$</td>
<td>0.25</td>
<td>$\Delta Q_{i,t}/Q_{i,t-1}$, $\Delta W_{i,t}/W_{i,t-1}$</td>
</tr>
<tr>
<td></td>
<td>(2.713)</td>
<td></td>
</tr>
</tbody>
</table>

$R^2$ 0.94
Wald test 17.84
$T^*$ 5

Notes: See the notes of Table 4.1.

The model was estimated in the simultaneous equation form (3.7)-(3.8). Since that model is static we do not need to take into account its initial conditions and, therefore, we ignore the equation (3.6). The unfilled vacancies variable contains the term planned employment level which is probably affected by the individual-specific attributes and therefore is correlated with the error term. In order to retain the consistency of the
parameter estimates the unfilled vacancies variable was instrumented by the percentage
cchanges in actual output and wage cost over the sample period. The instrumentation was
facilitated by equations (3.8)22.

Table 4.4
 Estimates of Output Level Expectations, Augmented Extrapolative Model
(Time Period: 1982-1988, Number of Firms in the Sample: 93)

<table>
<thead>
<tr>
<th>Dependent Variable: $Q_{i,t+1}$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Explanatory Instruments</strong></td>
</tr>
<tr>
<td>Variables $(s = 1982-1988)$</td>
</tr>
<tr>
<td><strong>M6</strong></td>
</tr>
<tr>
<td>Constant</td>
</tr>
<tr>
<td>(1.846)</td>
</tr>
<tr>
<td>$Q_{it}$</td>
</tr>
<tr>
<td>(37.993)</td>
</tr>
<tr>
<td>$Q_{i, t-1}$</td>
</tr>
<tr>
<td>(13.266)</td>
</tr>
<tr>
<td>$P_{i,t-1} \cdot \bar{Q}_{i}$</td>
</tr>
<tr>
<td>(1.893)</td>
</tr>
<tr>
<td>$R^2$</td>
</tr>
<tr>
<td>Wald test</td>
</tr>
<tr>
<td>$T^*$</td>
</tr>
</tbody>
</table>

Notes: Variable $\bar{Q}_i$ is the mean value of firm i's actual output level over the period 1982-1988.
See also the notes of Table 4.1.

The empirical results lend, in general, support to the hypothesis of the independent
effect of the two additional variables on the formation of wage cost expectations. From
the two value added variables only $VA_{H}$ turned out to be significant. As long as the
unfilled vacancies variables are concerned, $UNV_{AC}$ was found to be tolerably significant,

22 It is this kind of endogeneity that equations (3.8) are intended to facilitate. Yet, the kind of endogeneity
that arose in the previous section can equally well be facilitated by those equations.
while $UNVAC_{i,t-1}$ was clearly significant. The signs of the estimates are as anticipated: employers' propensity to raise wages increases with the contribution of the employees to the value added of the firm and the tightness in the labour market.

With $T^*=5$ and a critical value of 22.36 at the 5 per cent significance level, the Wald test do not reject the null hypothesis of correct model specification as the Wald statistic turned out to be equal to 17.84. In addition, the fit of the equation was very high ($R^2=0.94$). Thus, the two additional variables used in the specification of the augmented model for the cost of labour seem to be the only ones that exert an independent effect on the formation of expectations as to that variable.

Table 4.4 contains the results from the estimation of the augmented expectations formation model for output level. The additional variable used in this model is that of the expected (planned) output price, $P^*_{i,t+1}$. It is constructed as a weighted average of the expected price indices of output with weights equal to the relative share of expected sales at home and abroad. Hence, the variable captures firms' expectations as to the variations in the exchange rate also. We expect the coefficient of $P^*_{i,t+1}$ to be positive since a high expected price should stimulate firms to increase the level of output they plan to produce. Similarly with the expectational variables in previous models, $P^*_{i,t+1}$ is probably correlated with the error term and therefore the realised price index for output has been used as an instrument.

Before undertaking the estimation of model M6 one must pay attention to the fact that while expected and actual output are expressed in levels, expected price of output (and its instrument, realised price of output) is measured in relative terms since it is a price index. If the model is estimated as it stands, the estimated coefficient of variable $P^*_{i,t+1}$ will show the effect of a given change in the index of expected price on planned output irrespective of the order of magnitude of this output. In other words, the effect will be the same for all firms both small and large. This is however unrealistic and thus we will have to take the size of the firms into account during the estimation. A convenient way of doing that is to normalise the index for expected (and realised) output price with the size of the firms. One alternative is thus to multiply the series of these variables with the series of actual output and then undertake the estimation. As output has varied considerably over the sample period, however, the variation in prices which we are interested in may be obscured by the variation in output. What seems to be a more appropriate alternative is
to use each firm's average level of actual output over the sample period (1982-1988) for the normalisation of prices. Adopting this alternative provided the results reported in Table 4.4.

The sign of the estimate turned out to be positive as anticipated while the data provides support to the model as the very high $R^2$ value indicates. Most importantly, the Wald test does not reject the null hypothesis of correct model specification. The Wald statistic turned out to be equal to 21.82 with critical value equal to 30.14 for $T^* = 6$ at the 5 per cent significance level.

4.4 Summary

In the present chapter we estimated and tested different models of Swedish manufacturing firms' expectations as to their wage cost and output level. The first- and second-order adaptive model, Frenkel's error-correction model, and the simple acceleration model performed well in terms of parameter significance and parameter sign. The null hypothesis of correct model specification was rejected for the simple acceleration model both in the case of wage cost expectations and output plans. It was not rejected, however, for the rest of the models making the choice of the best model, in terms of specification, difficult. Nevertheless, Frenkel's model turned out to be superior to the rest in terms of equation fit.

Since the ability of the specification tests to discriminate among the alternative models turned out to be limited, we went on to consider models from the class of augmented extrapolative models also. Two members from the latter class were investigated, one for the labour cost equation and one for the output equation. In particular, labour cost expectations were allowed to be affected by current and once-lagged value added and unfilled vacancies, while output plans by current expected output price. In the former, lagged value added was shown to be insignificant, whereas the rest of variables turned out to be significant with anticipated parameter sign. The relevant test provided evidence in

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23 A third alternative would be the use of moving averages of actual output. However, although less volatile compared to actual levels of output, these averages would still exhibit a notable variation over time. Moreover, in panel data analyses this alternative would not be proved satisfactory as typical panel data comprises few observations on which the moving averages must be calculated.
support of the specification of the model. Expected output price turned out to have a significant effect on planned output level, as it was anticipated. Similarly with the labour cost model, the hypothesis of correct model specification was not rejected by the data.
Chapter 5

Investment Behaviour of Swedish Manufacturing Firms

5.1 Introduction

According to the standard neoclassical investment demand theory, the choice of the firm's capital stock is determined either by the cost of capital relative to the price of output or the cost of capital relative to the wage rate. The capital stock, in turn, determines the level of output which thus becomes endogenous. The implication of this for the investment process is that while changes in the cost of capital should affect investment, changes in the level of output should not.

Empirical implementations of the neoclassical investment model have provided results that contradict the predictions of this theory. In particular, changes in the level of output (accelerator effect) have been found to have a typically significant effect on the level of investment, but the effect of the cost of capital has usually turned out to be weak or insignificant. Empirical findings thus support the hypothesis that investment is driven by the demand for output rather than, or not only, by prices.

In the light of empirical evidence, studies on firm's investment behaviour have attempted to reconcile the predictions of the neoclassical investment theory with the facts by suggesting the formulation of the firm's optimisation problem in a way that allows the level of investment to depend both on quantities and prices. Shapiro (1986) derives a model according to which investment and output are strongly positively correlated while there is also a role for the cost of capital. In deriving his model, Shapiro assumes that the firm maximises the expected present value of its profits, given its expectations of prices, while it faces random, persistent output shocks24.

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24 See, however, the objections of Blanchard (1986) on the ability of this model to explain investment
An alternative line of research is that which considers the demand for the firm's output as exogenously given to the firm (see, e.g. Catinat et al. (1987), Mato (1989)). The firm's optimisation problem is formulated as one of cost minimisation where the firm minimises the expected present value of its total costs, given its expectations of the demand for its output and factor prices. The investment demand equation derived from this problem is a function of prices as well as output.

Besides the controversy about the importance of quantities and prices for investment, some other issues have been raised in the literature. One of them is the role of the firm's financial structure and financial policy for its real investment decisions. As demonstrated by Modigliani and Miller (1958), under the assumption of perfect capital markets the firm's financial and real decisions are independent. Drawing upon that result, the standard neoclassical investment model postulated that the firm's real investment behaviour could be described without any reference to its financial position. In the recent empirical literature, however, the assumption of the dependence between the two is usually made and the data typically provide support for that assumption (Fazzari, Hubbard and Petersen (1988), Catinat et al. (1987), Mato (1989)).

Another issue that has concerned the literature is that pertaining to the effect of unused capacity in the firm's production process on its capital building (Walfridson (1989), Bergström (1986), Bean (1981)). When capacity utilisation is low, one would expect that if more capital is necessary either in order to expand output or because of a change in relative input prices, the firm could simply utilise its free capacity without needing to increase its net investment.

The purpose of this chapter is to study the investment behaviour of Swedish manufacturing firms over the 1980s. In particular we are interested in identifying the factors and their relative importance that determine the Swedish firms' capital building. To this end we begin by assuming that the optimising firm aims at minimising its total production costs given its expectations of the demand for its output and the prices of the production factors. We also assume that the firm faces perfect input and capital markets and that it incurs increasing costs of adjusting its quasi-fixed factor capital. The derivation of the investment function is facilitated by techniques presented in the literature on dynamic factor demand models (Berndt, Fuss and Waverman (1977), Morrison and Berndt (1981)). In carrying out the the derivation, techniques developed by Sargent (1987) have been used.
Particular emphasis has been put on the uncertainty that surrounds the firm's investment decision-making and the implied necessity of expectations formation. Solutions to optimisation problems like the one postulated in this study are known to yield forward-looking decision rules due to the presence of adjustment costs (Eisner and Strotz (1963), Lucas (1967), Gould (1968)). Specifically, the firm's investment decision in each period is a function of its expectations of the entire future path of the exogenous variables. As mentioned in the previous chapter, this gives rise to considerable difficulties in empirical implementations of agents behaviour since data on expectations for such a long time period are usually not available. In addition, the theory does not provide any hints as to how these unobservable variables can be expressed in terms of observables. The practice in the literature has therefore been to incorporate the firms' expectations formation mechanisms - which are functions of observables - in the investment decision rule and let them generate the expectations.

The functional form of these mechanisms are decided outside and independently of the optimisation problem at hand. Yet, the choice of a particular functional form will determine the dynamic specification of the investment model, while at the same time it will implicitly assign specific attributes to the behaviour of the firm with regard to the degree of its rationality and comprehension of the functioning of the economic system. The classic partial adjustment model utilised by Jorgenson (1963) in his pioneering analysis of the firms' investment behaviour implicitly assumes static expectations on the part of the firms as this investment model is consistent only with this sort of underlying behavioural assumption. The static expectations hypothesis postulates that firms expect the values of the exogenous variables to remain the same over the entire future. The partial adjustment model has also been used in dynamic factor demand studies (Walfridson (1987,1989), Dargay (1988)).

The opposite case of the partial adjustment models are those models which maintain the Rational Expectations Hypothesis (R.E.H.) due to Muth (1960). As is well-known, the R.E.H. implies that expectations are formed in accordance to the true reduced form process that drives the variable as to which expectations are formed (Hansen and Sargent (1980,1981), Sargent (1981)). The R.E.H. hypothesis is admittedly rather strong since it assigns perfect knowledge of the economic system to the firms.

A third way of specifying the dynamic form of investment models is that based on the assumption that agents are boundedly rational. This category lies between the two extremes
of static expectations and rational expectations, and in deriving the investment demand equation expectations are allowed to follow a process from the class of ARIMA models (Harris (1985), Kokkelenberg and Bischoff (1986), Morrison (1986)).

Selecting the functional form of the expectations formation process on a priori theoretical grounds is an unsatisfactory procedure, for if this functional form happens to be wrong the derived investment model will be misspecified. As mentioned in Chapter 1, an elegant solution to this problem is the $Q$ model of investment ascribed to Tobin (1969). The model predicts that investment depends on marginal $Q$ which is defined as the ratio of the market value of an additional unit of capital to its replacement cost. Since the market value of capital ought to reflect the market judgement of the future stream of net earnings one does not need to measure expectations directly: all relevant information about expectations is summarised in the $Q$ ratio itself.

In empirical implementations of investment models of the flexible-accelerator type, however, the only satisfactory procedure to undertake with respect to the specification of the expectations formation mechanism is to resort to the data for their empirical determination. This was the subject of the previous chapter where the expectations formation of Swedish manufacturing firms were empirically studied. Apart from the emergence of a closed-form investment equation upon the substitution of the empirical expectations models in the decision rule, a set of additional explanatory variables will enter the investment equation. Although these variables do not appear in the firms' objective function from the beginning and therefore their inclusion in the investment model is not perfectly justified from the optimisation point of view, they are not refutable either as they were found to affect the expectations formation. After all, the optimisation problem is not solved until the 'true' expectations formation process has been incorporated into the decision rule and the investment equation has been obtained.

Before being implemented empirically, the optimal investment demand function is modified in two respects. First, we release the assumption of perfect capital markets and allow for the effect of the firm's financial condition on its investment spending. This effect is captured by incorporating the cash flow variable into the investment model. Second, we consider the necessary modifications in order to account for the effect of our assumption of boundedly rational economic agents on their investment behaviour. Since by definition this kind of agent fails to take into account all the relevant information when they form expectations, they will commit expectations errors which are not white noise processes. The firm's actual level of capital stock, based on imperfect expectations, will deviate from
the level of capital that would occur if the expectations were perfect. The discrepancy between the two levels of capital will obviously give rise to free capacity or capacity shortage in the firm's production process. Boundedly rational agents are expected to continue to make mistakes and to take them into account in subsequent investment decisions. We thus suggest two additional modification terms. First, the beginning-of-period deviation from full capacity utilisation which is known when the firm makes its investment plans for the period and, second, the revision of these plans by a portion of currently revealed expectations errors.

The disposition of the chapter is as follows. In Section 5.2 the optimal investment decision rule is derived from the stochastic cost minimisation problem of the firm under the assumption of perfect input and capital markets. The closed-form investment function is subsequently obtained upon the incorporation of the firm's empirical expectations formation mechanisms in the decision rule. Section 5.3 provides the justification for the modification of the optimal investment function and suggests the modification terms. Section 5.4 contains the empirical implementation. It is based on the IUI data described in Chapter 3. In the same chapter, the econometric methodology is also discussed. Two models are estimated in Section 5.4. The first is the model of the revision of investment plans and aims at facilitating the specification of the investment function with respect to the modification terms pertaining to the currently revealed expectations errors. The second model is the investment demand model. The interpretation of this model and a comparison with results from other studies is subsequently provided. The summary of the chapter is finally given in Section 5.5.

5.2 Derivation of the Investment Demand Equation

Assume there are two variable inputs (intermediate goods, \( M \), and labour, \( L \)), and one quasi-fixed input (capital, \( K \)) entering the firm's production process. Assume further that the firm faces perfectly competitive factor markets, where the two variable inputs can be purchased at prices \( P_M \) and \( P_L \), respectively, and capital can be purchased at asset price \( P_I \). Apart from purchase costs, changes in the quasi-fixed factor capital are assumed to incur additional costs to the firm in the form of adjustment costs. The rationale for this assumption is the necessary re-organisation of the production process of the firm when the stock of capital is altered. Following Berndt, Fuss and Waverman (1977, 1980), Morrison and Berndt (1981), and Kokkelenberg and Bischoff (1986), we let costs of
adjustment be internal and increasing in the absolute value of the rate of change of the capital stock. The former implies that costs of adjustment take the form of foregone output, whereas the latter that the fixed factor is available at increasing unit costs. Hence, the variation of capital stock is possible at a cost $C(\Delta K)$

$$\begin{align*}
C(0) &= 0, \\
C'(\Delta K) &= 0, \\
C''(\Delta K) &= 0,
\end{align*}$$

(5.1)

where $\Delta K$ is in absolute values, and $\Delta$ is the (backwards) difference operator with $\Delta K = K - K_{t-1}$.

Internal costs of adjustment are represented by the presence of $\Delta K$ in the firm's production function which can be written as:

$$Q_t = F(M_t, L_t, K_{t-1}, \Delta K_t, (t - 1)).$$

(5.2)

In the production function (5.2), $t-1$ represents the state of technology as measured by time, i.e. $t=1,\ldots,T$. The specification of the technology as $t-1$ indicates that it is the beginning-of-period state of technology that determines the production technology in each period. Similarly, the specification of the capital stock, $K_{t-1}$, indicates that only the stock in place at the beginning of the period is productive during the period.

The firm's explicit total costs, $V$, are given by:

$$V_t = (P M_t M_t + PL_t L_t) + PI_t (\Delta K_t + \delta K_{t-1})$$

$$= \tilde{C}_t + PI_t (\Delta K_t + \delta K_{t-1}),$$

(5.3)

where $\delta$ is the constant depreciation rate of the firm's capital stock.

The optimisation problem facing the firm is to choose, at each point in time $t$, the levels of production inputs $M, L$, and $K$ that minimise the expected present value of the cost of producing an expected path of output, $Q$, subject to the production constraint (5.2) and the initial stock of capital $K_{t-1}$.

A two-step procedure has been suggested in the literature for the solution of optimisation problems of this kind, drawing upon the distinction of the production factors in variable and quasi-fixed (Berndt, Fuss and Waverman (1979), Morrison and Berndt...
In the first step the firm is assumed to minimise its short-run variable cost, \( \hat{c}_t \). In the second step, it minimises the present value of its long-run expected costs, \( V_0 \). Thus, under the assumption of perfect certainty the firm's problem can be written as:

\[
\min V_0 = \sum_{i=0}^{\infty} \beta^i \{ \min \{ \hat{c}_i \} \} + \sum_{i=0}^{\infty} \beta^i P L_i (\Delta K_i + \delta K_{i-1}),
\]  

(5.4)

subject to an initial capital stock, \( K_{t-1} \), \( M_t \), \( L_t \), and \( Q_t \geq 0 \) for all \( t \), and exogenous prices and output. The discount rate \( \beta^i \) is defined as \( \beta^i = (1 + r_t)^{-i} \) where \( r \) is the appropriate nominal interest rate. \( \min \{ \hat{c}_i \} \) is conditional on \( K_{t-1} \), \( \Delta K_i \), and exogenous input prices and output.

Applying techniques due to Lau (1976), we employ a normalised version of \( \hat{c} \) in order to assure the appropriate properties for the short-run cost function. Hence, we define \( G = \hat{c} / P M \) and \( w = \frac{PL}{PM} \), and for the sake of consistency we also define \( q = \frac{P_I}{P M} \).

The optimal normalised variable cost function is denoted by \( G^* \) and is given by:

\[
G^*_t = \min \{ G(M_t, K_{t-1}, \Delta K_t, Q_t) \}.
\]

(5.5)

The firm's demand for the two variable inputs can be derived by Shephard's Lemma. Thus, the demand for labour is given by:

\[
L^*_t = [\partial G^*_t / \partial w_t].
\]

(5.6)

As \( G^* \) must be complete, i.e. \( G^*_t = w_t L^*_t + M^*_t \), the demand for intermediate goods is given by:

\[
M^*_t = G^*_t - [\partial G^*_t / \partial w_t] w_t.
\]

(5.7)

The above expressions provide the demand for variable inputs in a world of either perfect certainty or in a world of uncertainty.

The demand for capital stock can now be obtained from the first order conditions for a solution to (5.4). However, although the variable inputs may be adjusted to their optimal levels within one time period, the adjustment of the stock of capital to its optimal level stretches over several periods due to the presence of the increasing adjustment costs.
Hence, the formation of expectations is critical in this derivation and therefore the optimisation problem (5.4) will be specified as a stochastic one by appending an expectation operator, \( \mathbb{E} \), which indicates expectations taken at time \( t \).

With respect to the firm's formation of expectations we will assume that in making a decision at the beginning of period \( t \) to change the stock of capital in period \( t+1 \), the firm's formation of expectations is made with the information available at the beginning of period \( t \), i.e. the information from period \( t-1 \) and prior periods.

The stochastic optimisation problem can be written as follows:

\[
\min E_{t+0} V_0 = E_{t+0} \sum_{j=0}^{\infty} \beta^j P M_{t+j} \left[ G(w_{t+j}, K_{t-1+j}, \Delta K_{t+j}, Q_{t+j}) \right] \nonumber
\]

\[
(1 - 1 + j) + q_{t+j} (\Delta K_{t+j} + \delta K_{t-1+j})). \tag{5.8}
\]

Before proceeding to the derivation of the demand expression for capital stock we will focus on the role of interest rates in (5.8). Following Kokkelenberg and Bischoff (1986, p 426) we will transform the nominal interest rate into a real interest rate in the following way. Let \( \hat{P}_t = P M_t \). Note that \( P_t = P_0 (1 + \hat{P}_t) \) where \( \hat{P}_t \) is the per period time rate of change of the price of intermediate goods up to the \( t \)th period and \( P_0 \) is the price of intermediate goods in the initial period. Thus, \( \hat{P}_t = \hat{P}_0 (1 + \hat{\rho}_t)^t \). Assume that \( \hat{\rho}_t < \hat{\rho} \) for all \( t \). Let \( \hat{\beta}_t = (1 + \hat{\rho}_t)^{-1} \) and \( \beta_t = (1 + \hat{\rho}_t)^{-1} = \hat{\beta}_t^{1/t} \). Therefore, \( \beta^t P M_{t+j} \) in (5.8) can be replaced by \( P_0 \beta_t^{1/t} \), a type of real discount rate. We assume that the firm expects \( \beta_t^{1/t} \) to prevail from the \( t \)th period forward, and is based on expectations formed in the \( t \)th period.

By successive differentiation of the above optimisation problem with respect to \( K_{t+j} \), \( j = 0,1,2,... \), we obtain a set of stochastic Euler equations from which the investment decision rule can be derived. In order to carry out the optimisation we have to choose a functional form for the normalised restricted cost function. For most functional forms, finding an explicit solution to the stochastic Euler equations is an imposing, if not intractable, task. For one particular form, however, the derivation of the investment demand equation is relatively straightforward. This is the quadratic functional form since it is the specification for which the certainty equivalence principle holds (Sargent (1987), Ch. XIV). The principle implies that the optimisation problem can be decomposed into two independent components: i) the structural model of intertemporal optimisation based on unspecified expected
paths of future exogenous variables, and ii) the characterisation of the expectations formation process. Hence, instead of optimising the objective function (5.8) as it stands, it can be optimised with the stochastic variables replaced by their conditional expectations. The certainty equivalence analog to (5.8) thus becomes:

\[
\min E \sum_{j=0}^{\infty} \beta^j E\{G(E_{t+0}w_{t+j}, K_{t-1+j}, \Delta K_{t+j}, E_{t+0}Q_{t+j}, E_{t+0}(t-1+j)) + E_{t-0}[q_{t+j}](\Delta K_{t+j} + \delta K_{t+j})]\].
\]

Since \(P_0\) is a non-zero constant, we ignore it in what follows.

Following, e.g., Prucha and Nadiri (1986) we will specify the normalised restricted cost function as a quadratic form. Then, \(G(\cdot)\) reads:

\[
G = a_0 + a_t(t-1) + a_t w + a_K K_{-1} + a_\Delta K + a_Q Q + 0.5[b_{tt}(t-1)^2 + \sum b_{ij}^2 + b_{K,K} K_{-1}^2 + b_{K,K} \Delta K^2 + b_{QQ} Q^2] + b_{tK} w K_{-1} + b_{tK} w \Delta K + b_{tQ} w Q + b_{tt} w(t-1) + b_{K,K} K_{-1} \Delta K + b_{K,Q} K_{-1} Q + b_{K,K} K_{-1}(t-1) + b_{K,K} \Delta K Q + b_{K,K} \Delta K(t-1) + b_{Q,Q} Q(t-1).
\]

The regularity conditions for \(G(\cdot)\) are (Lau (1976)):

i) Increasing and concave in prices, which amounts to \(b_{tt} < 0\),

ii) Decreasing and convex in capital, which implies:

\[
\begin{align*}
* \frac{\partial G(\cdot)}{\partial K} &= a_K + b_{K,K} K_{-1} + b_{tK} w + b_{K,K} \Delta K + b_{K,Q} Q + b_{K,K} (t-1) < 0 \\
* \frac{\partial^2 G(\cdot)}{\partial K^2} &= b_{K,K} > 0.
\end{align*}
\]

25 The convenience offered by the certainty equivalence principle has been utilised in empirical studies where \(G(\cdot)\) is not specified as a quadratic function (see Morrison (1986)). This ambiguity is justified on the grounds of a suggestion given by Malinvaud (1969) that decisions made by optimising the objective function with the stochastic variables replaced by their conditional expectations are close enough approximations to those which would result if the expected values were maximised. However, the certainty equivalence principle holds strictly only if \(G(\cdot)\) fulfils certain conditions. These conditions are fulfilled by the quadratic functional form.
iii) Increasing and convex in net investment, which amounts to:

\[ \frac{\partial G(\cdot)}{\partial \Delta K} = a + b_{KK} \Delta K + b_{Lw} w + b_{KQ} Q + b_{Qt}(t-1) > 0 \]

\[ \frac{\partial^2 G(\cdot)}{\partial \Delta K^2} = b_{KK} > 0. \]

The portion in (5.10) representing internal cost of adjustment is:

\[ C(\Delta K) = a_{K} \Delta K + 0.5 b_{KK} \Delta K^2 + b_{Lw} w \Delta K + b_{KQ} Q + b_{Qt}(t-1) = 0. \] \hspace{1cm} (5.11)

At a stationary point where \( \Delta K \) must equal zero, marginal adjustment costs will be zero when:

\[ C'(\Delta K) \bigg|_{\Delta K=0} = a_{K} + b_{Lw} w + b_{KQ} Q + b_{Qt}(t-1) = 0. \] \hspace{1cm} (5.12)

This stationary condition will hold only if the following restrictions are imposed\(^{26}\):

\[ a_{K} = b_{Lw} = b_{KQ} = b_{Qt} = 0. \] \hspace{1cm} (5.13)

Then, the normalised variable cost function collapses to:

\[ G = a_{0} + a_{l}(t-1) + a_{L} w + a_{K} K_{-1} + a_{Q} Q + 0.5[b_{w}(t-1)^2 + b_{Lw} w^2 + b_{KQ} K_{-1}^2 + b_{KK} \Delta K^2 + b_{QQ} Q^2] + b_{Lw} w K_{-1} + b_{LQ} w Q + b_{Lt} w(t-1) + b_{KQ} Q_{-1} + b_{Qt} K_{-1}(t-1) + b_{Qt} Q(t-1) \] \hspace{1cm} (5.14)

Inserting (5.14) into (5.9) yields the final form of the optimisation problem from which the investment decision rule can be derived. This derivation is based on techniques ascribed to Sargent (in, e.g. Sargent (1987, Ch. XIV)), and is given in Appendix 5.A where the expression for the investment decision rule is shown to be as follows:

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\(^{26}\) These are the restrictions usually imposed in the literature on the portion of \( G(\cdot) \) representing internal costs of adjustment (see Morrison and Berndt (1981, pp. 347-348), and Kokkeelenberg and Bischoff (1986, p. 425)).
\[(1 - \lambda L)K_t = -\frac{1}{b_{Kt} \lambda} \sum_{i=0}^{\infty} \left( \frac{1}{\lambda} \right)^i \mathbb{E}_t \left[ \alpha_K + b_{tK} w_{t+i} + b_{Q} Q_{t+i+1} \right] + b_{Kt}(t+i) + \frac{1}{\beta_t} q_{t+i} - (1 - \delta) q_{t+i+1}, \quad (5.15)\]

where \(\lambda\) and \(\lambda^*\) are functions of the parameters of the cost function \(G(\cdot)\). They are also functions of the discount rate \(\beta^*\) and thus vary through time. The lag operator \(L\) is defined as \(L^n x_t = x_{t-n}\). The expectation operator, \(\mathbb{E}_t\), indicates expectations taken at the beginning of period \(t\) based on information from period \(t-1\) and prior periods.

The last two terms in (5.15) constitute the well-known user cost of capital variable. Recalling our assumptions about the properties of the three constituent components of this variable, we notice that we have implicitly assumed that the firm forms expectations in a different way as to the three different components. The depreciation rate of capital stock, \(\delta\), has been assumed to remain constant over time and, thus, there is no need for the firm to form expectations of that at all. With respect to the discount rate, \(\beta^*\), we have assumed that it is based on expectations taken in time period \(t\) and that the firm expects it to prevail from the \(i\)th period forward. The implication of this is that the firm's expectations as to that variable are static. Finally, since a different value of the (normalised) price of investment goods is expected for each future time period, the expectations as to that variable are formed non-statically.

For the sake of convenience in the forthcoming empirical implementation, we will specify the user cost of capital as one term rather than as two as it appears in expression (5.15). In addition, in constructing its empirical counterpart we will abstract to some extent from its theoretical specification and employ a specification which is closer to that usually found in the empirical literature (see Dargay (1988)).

The two terms that constitute the cost of capital can be written as follows:

\[
\frac{1}{\beta_t} q_{t+i} - (1 - \delta) q_{t+i+1} = (1 + r_i - \hat{p}_i) q_{t+i} - (1 - \delta) q_{t+i+1} = (r_i - \hat{p}_i) q_{t+1} + \delta q_{t+i+1} - (q_{t+i+1} - q_{t+1}),
\]
where \( (r_t - P_t) \) is a type of real interest rate and the last term is the revaluation term. The above expression will be approximated by \( q_{t+1} = q_{t+1} (r_t - \pi_t + 0.04 + \delta) \), where \( \pi \) denotes inflation and a 4% risk premium has been added to the real interest rate. The subscript \( t \) appended to variables \( r \) and \( \pi \) indicates expectations formed statically in period \( t \). Expectations as to \( q_{t+1} \), are, however, formed non-statically due to the presence of \( q_{t+1} \) in the specification of that variable.

According to (5.15), the firm’s investment expenditure in each time period is a function of the expected future time paths of the exogenous prices (wage cost, \( w \), and user cost of capital, \( q \)) and output level, \( Q \). It is also a function of the future state of technology as measured by time, \( t \). As indicated by the subscript of the expectation operator, the expectations for period \( t+1 \) and forward are formed on the basis of the information available at the beginning of period \( t \), i.e. the information from period \( t-1 \) and prior periods. In order to implement (5.15) empirically we need to know the expectations of the firm for the entire future. As data on expectations formed at a particular date for several future dates are not generally available, we will insert the firm’s expectations formation mechanisms into (5.15) and let them generate the expectation values. Since the expectations formation mechanisms can be specified as functions of observables the empirical implementation of the investment demand function is facilitated. The dynamic specification of demand equation (5.15) will depend on the particular models we assume or empirically show to best describe the firm's expectations formation mechanisms. The disadvantage with assuming models for these mechanisms is that if these models happen to be wrong, the investment demand equation will be misspecified. Therefore, we will make use of our results from the empirical analysis of the firm’s expectations formation presented in Chapter 4.

Our preferred model from the class of purely extrapolative models for the labour cost and output level was Frenkel’s error-correction model. Yet, as it stands, this model is not suitable for the present purpose: the model predicts the adjustment of expectations in each time period while equation (5.15) calls for a forecasting device that will generate point expectations for the entire future. Such a device is the ARIMA process which, when it drives the variable as to which expectations are formed, Frenkel’s model yields optimal adjustments of expectations. The point expectations that we are looking for are the optimal forecasts made by this process. Since, as was shown in the previous chapter, Frenkel’s model is optimal if the underlying variable is driven by approximately an ARIMA (1,1,1) process, the latter will be incorporated in equation (5.15) which thereby becomes estimable.
It should be noticed that the reasoning does not necessarily imply that the underlying variable is actually driven by an ARIMA (1,1,1) process. It just says that since the observed expectations adjust according to Frenkel's model, we would expect the firms to believe that the underlying variable follows an ARIMA (1,1,1) process. They may well be wrong in which case an expectations error will occur.

In Chapter 4 we also found significant effects on expectations formation of variables other than the expectational variables' own past history. These were the effects of value added and unfilled vacancies on expected labour cost, and expected output price on planned output level. These variables represent information readily available to firms at the moment of expectations formation, and we will have to consider them when specifying the empirical counterpart to the demand equation (5.15). Thus, the expectations mechanism for labour cost will be specified as an ARIMA(1,1,1) process plus the current and once-lagged unfilled vacancies. The latter are simply appended to the ARIMA model without allowing any interaction with it as they are intended to capture an independent effect on expectations. We drop the value added variable because its effect turned out to be very low. Similarly, planned output will be specified as an ARIMA(1,1,1) process plus the expected output price which we also need to express in terms of observables. We therefore assume that price expectations also follow an ARIMA(1,1,1) process. In specifying the expectations formation mechanism for the user cost of capital we assume no independent effect from any additional variables than those describing its own past history, and, similarly with the other specifications, we let it follow an ARIMA(1,1,1) process. Finally, we assume static expectations with regard to the state of technology. Inserting the four expectations formation mechanisms in the decision rule (5.15) we derived the following estimable investment demand equation (see Appendix 5.B for the derivation):

$$\Delta K_i = \alpha_K \Delta K_{i-1} + \frac{\lambda - 1}{b_{KK}} \left[ b_{LK} w_{i-2} + b_{LQ} b_w \Delta w_{i-1} + b_{LQ} b_q \Delta Q_{i-1} + b_{KQ} b_p \Delta P_{i-1} + b_{KQ} \bar{Q}_{i-2} + \bar{Q}_{i-1} \right] + \left( \lambda - 1 \right) K_{i-1},$$

(5.16)

where \( b_i = 1/(1 - \phi_i) \left[ 1 - \phi_i^2 (\lambda' - 1)/(\lambda' - \phi_i) \right], \ i = w, Q, P, \bar{Q}, \) and \( \phi, \alpha, \alpha_2 \) and \( \beta \) are parameters of the expectations formation processes.
5.3 Deviations from the Optimal Investment Function

The investment demand function (5.16) describes the investment behaviour of the firm given the assumptions underlying the optimisation problem (5.8), and the assumption regarding the formation of expectations as described by the expectations formation mechanisms. At the prospect of the forthcoming empirical implementation we will in this section suggest the modification (augmentation) of (5.16) in two respects. On the one hand, the assumption of perfect capital markets which underlies the optimisation problem will be relaxed. On the other hand, the effects of the firm's expectations errors, following from our assumption of boundedly rational economic agents, on its investment spending will be considered.

5.3.1 Capital Market Imperfections

The perfect capital market hypothesis postulates that all firms have access to centralised securities markets where they face a cost of capital set in these markets. As demonstrated by Modigliani and Miller (1958), the implication of this hypothesis is that the firm's financial structure and financial policy is irrelevant for its real investment as external funds provide a perfect substitute for internal capital. Hence, financial factors such as internal liquidity, debt leverage, or dividend payments are independent of the firm's real decisions.

Early studies on the firm's investment behaviour emphasised the interdependence of the firm's real investment and financial decisions (Meyer and Kuh (1957)). The subsequent dominance of Jorgenson's neoclassical investment theory, however, contributed to the separation of these two. Jorgenson himself formulated the firm's intertemporal optimisation problem without any reference to financial factors (Jorgenson (1963), Hall and Jorgenson (1967)). In the recent literature on investment and finance, however, the perfect capital market hypothesis has been put in doubt. The preferred hypothesis in this literature is rather that of the imperfect capital markets and imperfect substitutability between external and internal financing with the latter providing a cost advantage over the former. The implication for the study of real investment behaviour is the emphasis put on the interdependence of the firm's financial and real decisions.
The foundation for the cost advantage of internal over external financing is usually provided by appealing to a number of reasons (see, Ross et al. (1988) pp 417). First, there are transaction costs associated with the issue of new debt and equity capital, such as underwriting discounts, administrative expenses, taxes, etc. Second, the corporate tax system in many countries (Sweden among them) has historically provided a cost advantage to internal equity finance over external equity finance. This cost advantage emanates from the difference between the effective tax rate on capital gains and dividends in favour for the former. Third, there are costs of financial distress associated with the issue of new debt. Financial distress costs arise when a firm has difficulties meeting its principal and interest obligations (the extreme case being bankruptcy). As this is more likely to occur when the leverage of the firm is high (the ratio of its debt to its equity), the firm faces an increasing marginal cost of new debt. Finally, there are costs associated with imperfect information on the part of lenders about the investment opportunities of the firm. For most providers of external capital it is difficult, even impossible, to evaluate the quality of such investment opportunities. As a compensation for this kind of risk taken, an extra risk premium is demanded which further increases the cost of external financing.

Thus, what firms experience is a cost differential between internal and external financing that may constrain their investment spending. When investment demand is low, capital spending can be financed from internally generated funds at low cost. As investment demand increases, firms with low cash flows will have to resort to high-cost external financing. In the margin, the cost for this kind of financing may exceed the expected return from desirable investment projects which, in this case, will have to be suspended. Under these circumstances, firms' investment demand may be constrained by the lack of availability of internally generated funds. In order to allow for this possibility, we will include the cash flow variable in the investment equation along with the standard cost of capital variable.

5.3.2 Unused Capacity and Investment Plans Revision

The investment decision rule (5.15) predicts that the optimal level of capital stock in each time period is given by the firm's expectations of the future time paths of the exogenous variables. Yet, this decision rule says nothing about how these expectations are formed. The issue that concerns us here is the implications for the specification of the closed-form investment function of our assumption of boundedly rational economic agents which
underlies the specification of the expectations formation processes. Related to this issue is also the question of in which sense the behaviour described by (5.15) is optimal if the firm's expectations are formed non-optimally. In an attempt to illuminate these issues we will consider the cases of perfectly rational and boundedly rational economic agents.

Consider first the case of a perfectly rational agent, in the sense of Muth (1961). The agent forecasts the future market conditions in order to decide about the optimal level of investment to be undertaken during the current period. Being rational, the agent utilises all the relevant information and forms optimal forecasts of the exogenous variables which after being incorporated into the investment decision rule provide the optimal level of investment. The forecasts are optimal in the sense that their values deviate from the subsequently revealed actual values of the exogenous variables only by a white noise error. The level of investment is optimal from a purely analytical point of view (i.e. it is the solution to the optimisation problem given some set of expectations values), and it is also the best level of investment since it is in accordance with the realised economic conditions.

Under the assumption of boundedly rational agents, however, the forecasts of the exogenous variables are not optimal, since by definition the agents fail to take into account all the relevant information when they form expectations. Expressed in terms of the expectations formation mechanisms this implies that these mechanisms do not coincide with the "true" reduced form processes that drive the variables as to which expectations are formed. The difference between the two will be a function of terms such as lagged realisations, of a particular order, of the expectational variables and a set of additional explanatory variables omitted from the expectations formation mechanisms. From an analytical point of view, the investment decision rule provides optimal levels of investment in this case also. From the economic point of view, however, this investment level is not the best possible since it is not in accordance with the actual economic conditions subsequently revealed. The difference between the level of investment predicted by (5.15), or rather by (5.16) when the firm's expectations formation mechanisms are incorporated in (5.15), and the best possible will be proportional to the firm's errors in expectations, which will not be white noise processes and will result in unutilised capacity or capacity shortage in the firm's production process.

What will be the firm's reaction to these expectations errors? A conceivable reaction could be the firm's attempt to improve the forecasts of the exogenous variables through a change in the specification of its expectations formation mechanisms. Two objections can be raised against this alternative. First, in the light of new expectations errors, successive
improvements of these mechanisms will ultimately result to their convergence to the mechanisms that generate optimal forecasts, which contradicts our bounded rationality hypothesis. Second, even if the expectations formation mechanisms are successively altered, any notable effect on the specification of these mechanisms, and of course on the specification of the investment demand function also, will be apparent only in the long-run, due to inertia in the behaviour of economic agents. What seems more reasonable is to assume that the firm, utilising relatively stable expectations formation mechanisms, will continue to make mistakes and that it will adjust its investment spending taking into consideration those mistakes. In this event, we would expect expression (5.16) to provide a rather accurate description of the firm's investment behaviour but with a modification (augmentation) for its reaction to the observed expectations errors.

At the beginning of each time period, when the firm decides about the level of investment to be undertaken during the period, the magnitude of its past expectations errors is known and equal to the unutilised capacity. The latter will probably affect current investment spending, for if the firm needs more capital either in order to expand output or because of a change in the relative input prices, it can simply utilise its free capacity without needing to increase net investment. Based on similar arguments, the degree of capacity utilisation has, in the literature, been incorporated into empirical investment functions (Bean (1981), Bergström (1986)).

During the current period, information will arrive at the firm about the realised values of the exogenous variables. Then, the firm will be able to observe the expectations errors revealed during the current period by comparing the realised values with the forecasts. There are two conceivable reactions to the currently revealed errors. First, the firm may take them into account first at the beginning of the subsequent period when it plans for that period's investment spending. Second, the errors may affect the current period's investment level through the revision of the current period's investment plans made at the beginning of the period. Since by the assumption of bounded rationality the expectations errors contain information not taken into account when the expectations were formed, it should be in the interest of the firm to revise its investment plans in the light of now revealed relevant information. Yet, there are costs associated with the revision of investment plans which probably increase with the extent of revision. Therefore, we would expect that an optimising firm will revise its investment plans up to the point where the benefit from the revision equals the cost of the revision.
The implications of the occurrence of expectations errors that are not white noise processes for the specification of the investment demand equation can thus be summarised as follows. First, current investment is affected by accumulated past errors, known at the moment of investment decision-making. Second, currently revealed expectations errors will have an effect on current investment spending through the revision of current investment plans. The effect will be only a portion of these errors with the remaining portion affecting the level of investment in the subsequent period.

5.4 Empirical Implementation

5.4.1 Empirical Model and Expected Results

The investment demand equation that we set out to estimate and test can be written in the following empirical form:

\[
I_{it} = \alpha_0 + \alpha_1 I_{i,t-1} + \beta_1 w_{i,t-2} + \beta_2 Q_{i,t-2} + \beta_3 q_{i,t-2} + \beta_4 (t-1) + \\
\beta_5 \Delta w_{i,t-1} + \beta_6 \Delta Q_{i,t-1} + \beta_7 \Delta q_{i,t-1} + \gamma_1 \Delta UNV AC_{i,t-1} + \\
\gamma_2 \Delta UNV AC_{i,t-1} + \gamma_3 \Delta p_{i,t-2} + \gamma_4 \Delta p_{i,t-1} + \delta_1 CF_{it} + \delta_2 Q_{-ERR} + \\
\delta_3 K_{i,t-1} + \delta_4 (1 - \Delta CU_{i,t-1}) K_{i,t-1} + \nu_{it}
\]

\[(5.17)\]

where \(i = 1,2,\ldots,N\) indexes firms and \(t = 1,2,\ldots,T\) denotes time periods.

Model (5.17) is an error-component model with \(\eta_i\) representing firm-specific effects such as managerial ability, norms and habits, and is intended to capture the heterogeneity in the firms’ behaviour. It is a priori assumed to remain constant over time with zero mean and constant variance \(\sigma^2_{\eta}\). Component \(\epsilon_{it}\) is the transitory component of the error term which, under the assumption of correct model specification, will have zero mean and constant variance \(\sigma^2_{\epsilon}\).

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Comparison of (5.17) with the theoretical model (5.16) reveals that the coefficients of the former are highly non-linear functions of parameters characterising the technology of the firm and the expectations formation processes. They are also functions of the parameter $\lambda$, which depends on the real discount rate $\beta^*$ and thus varies through time. No attempt has been made to estimate the values of these deeper parameters as this is not our primary interest. We are more interested in identifying the determinants of investment and their relative importance. For this purpose, the estimates of the parameters of the empirical model (5.17) would do. We need to assume, however, that the deeper parameters remain constant over time. This assumption has already been made earlier with respect to the parameters of the expectations formation mechanisms (see Section 5.3.2). We retain it here and extend it to apply to the parameters of the technology also. With respect to $\beta^*$ we will assume that the firm acts as if its value does not change considerably from one period to the next. In that case, parameter $\lambda$ would be expected to remain largely constant over time. A justification for this assumption can be provided by appealing to the short time period covered by the utilised data and the lack of turmoils in Swedish capital market during that period.

The dependent variable, $I_{u}$, in (5.17) is the level of real net investment in machinery and construction. It equals real gross investment less depreciation. The lagged endogenous variable, $I_{u,t-1}$, is "generated" by the moving average part of the expectations formation mechanisms of the firms. The coefficient of this variable should be less than one in absolute value if (5.17) is to be a stationary process.

The explanatory variables $w$, $Q$, and $\tilde{q}$ appear both in twice-lagged levels and lagged first differences due to our assertion, based on previous empirical results, that the formation of expectations as to these variables follows an ARIMA process, the autoregressive part of which is of order one. Higher order autoregressive processes would result into successive increases of the number of variables in first differences (Nickell (1985)). We have not tested empirically if the order of the autoregressive processes is higher than one. The economic content would be rather limited anyway. What seems to be of greater interest is to test whether, in the present context, the firms' expectations are static or non-static. The later hypothesis is the most reasonable one and it will be accepted if the coefficients of the variables both in twice-lagged levels and lagged first differences turn out to be

\[ 27 \text{ Descriptive statistics of this and the rest of variables are given in Appendix 3.A to Chapter 3.} \]
significant. Significant coefficients of the variables in \textit{once-lagged} levels would provide support for the hypothesis that expectations are formed statically. However, none of the three variables, $w$, $Q$, and $q$, appear in once-lagged levels in equation (5.17). Nevertheless, since the values of these variables lagged once and twice are probably highly correlated, the hypothesis of static expectations can be accepted if the variables in twice-lagged levels turn out to be significant while those in first differences insignificant.

The sign of the labour cost coefficients, $w_{i,t-2}$ and $\Delta w_{i,t-1}$, should be positive since an increase in labour cost would provide incentives to the firms to move to more capital intensive production processes by increasing investment expenditures in new capital. On the contrary, the higher the user cost of capital, $q_{i,t-2}$ and $\Delta q_{i,t-1}$, the lower the level of investment outlays. The user cost of capital variable comprises the purchase price of investment goods, the real market interest rate, and the depreciation rate of real capital. An increase in any of these variables would make investment projects more expensive and therefore we should expect investment expenditures to be curbed. On the other hand, a rise in output level, $Q_{i,t-2}$ and $\Delta Q_{i,t-1}$, (and of course sales) should stimulate investment resulting in a positive effect on investment expenditures. It is, however, changes in output, $\Delta Q_{it}$, that should have a significant effect on investment. This is in line with the basic accelerator principle which as known relates the desired capital stock to the level of output and, therefore, investment to the change in output.

The estimates of the variables in first differences are intended to capture the short-run effect of these variables on current investment spending. The (two-year) long-run effects, on the other hand, are functions of the estimates of the variables in levels and will be obtained from the long-run solution of the estimated equation (5.17).

Variable $w$ is the labour cost index (including employers' contribution to social security) at the firm level, normalised by the intermediate goods price index at branch level, obtained from the National Accounts. Variable $q$ equals $q(r - \pi + 0.04 + \delta)$ where $q$ is the investment goods price index normalised by the intermediate goods price index (both indices at branch level), $r$ is the interest rate on five-year government bonds, $\pi$ is the rate of inflation, 0.04 is an arbitrary risk premium of four per cent, and $\delta$ is the real capital depreciation rate that varies over firms but remains the same through time. The investment goods price index was constructed as the weighted average of the corresponding indices for machinery and construction with weights equal to the share of the two kinds of assets in real current gross total investment. Similarly, $\delta$ was constructed as the weighted average
of the depreciation rates for the two kinds of assets with weights equal to the relative portion of machinery and construction stocks in total real capital stock. Finally, \( Q \) equals production volume at the firm level.

The unfilled vacancies, \( \text{UNVAC}_{i,t-1} \) and \( \text{UNVAC}_{i,t-2} \), and price of output, \( P_{i,t-2} \) and \( \Delta P_{i,t-1} \), variables were introduced in equation (5.17) because of their effect on the formation of expectations as to the labour cost and the level of output, respectively. In other words, these two variables are not expected to exert any direct effect on the level of investments but only indirectly, and we have to take that into account when forming our anticipation as to their signs. It is, however, of interest to consider whether these variables could have any conceivable direct effect on investment that possibly runs in the opposite direction than the effect through the expectations formation mechanisms. In that case, the sign of these variables would depend on the relative strength of the two opposite effects.

There does not seem to be any ambiguity with respect to the sign of the price of output. As we found in Chapter 4, the effect of this variable on planned output level was positive. Since output is expected to have a stimulating effect on investment, the sign of its price should be positive. With regard to a likely direct effect on investment we can hardly imagine that this could be other than positive. Hence, the sign of \( P_{i,t-2} \) and \( \Delta P_{i,t-1} \) is expected to be positive. Variable \( P \) is the output price index constructed from the series of output level in current and constant prices at the firm level. Similarly with the other price indices, this index has been normalised by the intermediate goods price index.

Consider now the expected sign of unfilled vacancies, \( \text{UNVAC}_{i,t-1} \) and \( \text{UNVAC}_{i,t-2} \). Their effect on expected labour cost turned out to be positive, which is in accordance with basic economic theory that excess demand drives prices up. High labour costs, in turn, imply high investment spending and, therefore, we would anticipate a positive coefficient for the unfilled vacancies variables. The anticipation is reinforced by the consideration of a possible direct effect of \( \text{UNVAC} \) on the investment level. We could namely expect that if firms cannot fill their vacancies they would have incentives to resort to more capital intensive production processes through an increase in investment spending. However, as seen in Chapter 2, Swedish firms faced a very high shortage of skilled labour during the 1980s. As capital intensive production processes are operated by skilled employees, lack of the latter could probably discourage the firms from investing in such processes. Variable \( \text{UNVAC} \) includes, by construction, the unfilled vacancies of both unskilled and skilled labour. Its effect on investment spending should therefore depend on the relative importance of the two. Ideally, one should include the unfilled vacancies for both unskilled
and skilled labour in the investment model with positive expected sign for the former and negative for the latter. However, due to the lack of access to this kind of disaggregated data, the estimation of the effect of UNVAC for skilled and unskilled labour separately is not possible. Variable UNVAC was constructed as the difference between planned employment level and actual employment level, divided by the actual employment level, times one hundred. It is, thus, equal to unfilled vacancies in per cent of actual employment.

The cash flow variable, $CF_{it}$, is intended to capture the positive effect of the availability of internally generated funds on investment expenditures. As argued earlier, cash flow has a cost advantage over externally provided financing, and on the margin a shortage in cash flow may constrain the level of capital spending. Therefore, the sign of its coefficient is expected to be positive. The cash flow variable is measured here as operating cash flow. It was constructed as value added minus labour cost, less taxes arbitrarily set equal to 30 per cent of this difference. The 30 per cent tax rate is in accordance with earlier results about Swedish firms’ effective tax rate. All variables were measured in current prices at the firm level.

Current investment spending is also affected by excess capacity or capacity shortage in the firm’s production process. Deviations from full capacity utilisation are the result of current and past expectations errors. The inclusion of these errors for each explanatory variable separately would increase the number of parameters substantially. In order to keep the model parsimonious, a selective procedure was applied for the choice of current expectations errors to be included in the model, while past expectations errors were proxied by unutilised capacity. As argued earlier, current unfulfilled expectations will probably result in investment plans revisions. Running a regression of the former on the latter will provide empirical evidence of the expectations errors of those variables that exert a considerable effect on the firms’ investment plans revisions and thus on their investment expenditures. The results from the regression are reported in the next section. From the three variables considered (errors in expected labour cost, production level and output price) only unfulfilled production plans, $Q_{ERR_{it}}$, were found to have a significant effect on investment revisions. This is therefore the only current expectations error included in the empirical investment demand equation. It is constructed as the discrepancy between planned and actual output level, and its sign should be negative as a lower than planned output should have a negative effect on investment spending.
Unutilised capacity was constructed as \((1 - CU_{i-1})K_{i-1}\) where \(CU\) stands for capacity utilisation and \(K\) for real total capacity stock. Since the beginning-of-period value of the variable is relevant, deviations from full capacity are lagged once.

5.4.2 Estimation, Testing, and Presentation of the Results

In this section we present the results from the estimation and testing of two models. The first one is a model of the revisions of firms' investment plans. The aim with this analysis is to provide empirical support for our assertion that investment plan revisions are necessitated by currently revealed errors in expectations. In addition, for the sake of specification of the investment equation, we need to find out the expectations errors of those variables that have a considerable effect on the firms' investment plans revisions. Finally, as investment revisions are an important part of the firms' investment behaviour, they deserve an empirical analysis on their own. In the second part of this section we present the results from the estimation and testing of the empirical investment demand model.

5.4.2.1 Investment Plans Revision

We postulate the following empirical error-component model for the revisions of investment plans:

\[
IREV_{it} = \alpha_0 + \alpha_1(w_{it}^e - w_{it}) + \alpha_2(Q_{it}^e - Q_{it}) + \alpha_3(p_{it}^e - p_{it}) + u_{it}
\]  

(5.18)

where \(i = 1, 2, \ldots, T\) and the components of the error term are assumed to have the same properties as those of model (5.17) above.

According to (5.18), investment plan revisions in the current period, \(IREV_{it}\), are a function of expectations errors in current labour costs \((w_{it}^e - w_{it})\), production level \((Q_{it}^e - Q_{it})\) and sales price \((p_{it}^e - p_{it})\) (the superscript \(e\) stands for expected value). The
only variable as to which, we have assumed, firms have non-static expectations and which is not included in (5.18) is the user cost of capital. This is because of lack of access to direct measures of expectations for that variable.

Variable $IREV_{it}$ was constructed as the difference between planned and actual real net total investment. The construction of the expectational terms in the explanatory variables of equation (5.18) parallels that of their realised counterparts. Since we lack direct measures of expectations on intermediate goods prices, however, the expected labour cost and the expected output price were normalised by the realised intermediate goods price.

The sign of $(w^*_it - w_{it})$ is expected to be positive. Since we have previously assumed that an increase in labour cost stimulates investments, a realised labour cost that turned out to be below expectations should ease the need for immediate capital expansion. Therefore, investment plans could be revised towards lower levels. A similar effect can be assumed for errors in production plans. If output and sales turn out to be lower than planned, some investment projects will have to be suspended if excess capacity is to be avoided. Hence, the effect of expectations error in planned output on investment revisions should be positive. Positive should be the coefficient of $(\rho_{it}^* - \rho_{it})$. As the expected price of output was found to exert a positive effect on $Q^*_u$, a realised price of output that turned out to be lower than expected could result into a downward revision of investment plans. The same effect on $IREV_{it}$ of an expectations error in output price could be anticipated in the case of a likely direct positive effect of the price of output on investment. If the former turned out to be lower than expected, its effect on the latter would be weakened. In that event, there might be some incentives on the part of the firm to revise its investment plans downwards.

The random-effects model (5.18) has been estimated as a simultaneous equations system the general form of which is given by (3.6-3.8) in Chapter 3. Since model (5.18) is a static one, i.e. no lagged dependent variables appear in the right-hand side of the model, we do not need to specify any initial conditions and therefore equation (3.6) has been excluded from the system. System (3.7) consists of six equations, one for each time period that observations are available (it turned out that data were available over the period 1983-1988). System (3.8) facilitates the modelling of the endogenous explanatory variables in terms of exogenous variables. We have reason to believe that all the explanatory variables in (5.18) are endogenous. As we stressed in the previous chapter, the expectational terms
that are part of these variables are correlated with the time-invariant individual specific effects which are included in the error term. As shown by Hausman and Taylor (1981), for fixed number of time periods $T$, ignoring this correlation will render the estimates of the model inconsistent. Therefore, we use changes in realised values of the corresponding variables over the period 1983-1988 as instruments for each one of the explanatory variables in every equation of system (3.7). Hence, since there are three explanatory variables in each equation and we have six equations, system (3.8) consists of eighteen equations. The fit of these equations turned out to be rather high, a fact that was used as a criterion, apart from exogeneity, for the choice of the proper instruments. In total, system (3.7) and (3.8) comprises twenty-four equations. Cross-equations linear restrictions were imposed in system (3.7), while system (3.8) was estimated unrestricted.

Similarly with the augmented model of output expectations in Chapter 4, the price variables of model (5.18), $(w_{it}^\circ - w_{it})$ and $(p_{it}^\circ - p_{it})$, as well as their instruments, $\Delta w_{is}$ and $\Delta p_{is}, t = 1983-1988, s = 1982-1988$, must be normalised prior to the estimation. To this end, these variables were multiplied by the mean value of each firm's output level, $Q_t$, over the period 1982-1988.

The results from the empirical implementation of model (5.18) are shown in Table 5.1. Expectations errors in labour cost and price of output turned out to have an insignificant effect on current investment revisions. On the contrary, unfulfilled output plans were found to affect significantly current investment revisions. The sign of $(Q_u^* - Q_u)$ was positive as anticipated providing evidence that firms revise their investment plans downwards due to unexpectedly low output level. If they do not, an undesirable excess capacity will be created.

The fit of the whole system was rather high as indicated by the $R^2$ value which equals 0.84. The fit of each equation in the system was also high and in general close to the system fit.

In Table 5.1 we also report the result of the test of correct model specification. It is a Wald test of the null hypothesis that the transitory component $\epsilon_u$ of the error term $\nu_u$ of system (3.7) is a random walk process. This amounts to testing whether the elements on the principal diagonal of the covariance matrix are equal to each other and the remaining elements are all equal to one another. The Wald statistic is distributed asymptotically as $\chi^2_{0.05}$, where the number of restrictions, $r$, equals $T^* (T^* + 1) / 2 - 2$, and $T^*$ is the number of equations in system (3.7). The null hypothesis is not rejected. The value of Wald statistic is equal to 26.00 with relevant critical value equal to 30.14 for $T^* = 6$ at the 5 per cent.
## Table 5.1
Estimates of Investment Plans Revision Model
(Time Period: 1983-1988, Number of Firms in the Sample: 93)

<table>
<thead>
<tr>
<th>Dependent Variable: $REV_{it}$</th>
<th>Instruments ($t = 1982$-1988)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Explanatory Variables</strong></td>
<td><strong>Instruments</strong></td>
</tr>
<tr>
<td>Constant</td>
<td>3536.41 (2.948)</td>
</tr>
<tr>
<td>$(w_{it}^{<em>} - w_{it})</em>\bar{Q}_{i}$</td>
<td>0.00003 (0.846)</td>
</tr>
<tr>
<td>$(Q_{it}^{*} - Q_{it})$</td>
<td>0.04 (5.879)</td>
</tr>
<tr>
<td>$(p_{it}^{<em>} - p_{it})</em>\bar{Q}_{i}$</td>
<td>0.000003 (0.478)</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.84</td>
</tr>
<tr>
<td>Wald test</td>
<td>26.00</td>
</tr>
<tr>
<td>$T^*$</td>
<td>6</td>
</tr>
</tbody>
</table>

**Notes:**

i) t-values in parentheses.

ii) The Instruments in the last column are the explanatory variables in models (3.8).

iii) Variable $\bar{Q}_{i}$ is the mean value of firm $i$'s actual output level over the period 1982-1988.

iv) Statistic $R^2$ is a system statistic and therefore affected by the fit of the equations in the whole system (3.7)-(3.8).

v) $T^*$ is the number of equations (i.e. number of time periods) in the equations system (3.7) alone. It does not include the number of the equations in system (3.8).

vi) The Wald statistic concerns the test of the hypothesis that the elements on the principal diagonal of the covariance matrix of system (3.7) are equal to each other and the remaining elements are all equal to one another. It is distributed asymptotically as $\chi^2_r$, where the number of restrictions, $r$, equals $T^* (T^* + 1)/2 - 2$.

---

Significance level. This implies that the data provide support to the specification of model (5.18). Hence, in the light of this result and the high value of the $R^2$ statistic, we conclude...
that unfulfilled output plans account for the greater part of current investment revisions and therefore we let \((Q^a - Q^n)\) to be the only expectations error that enters the investment demand equation.

### 5.4.2.2 Investment Demand

We now turn to the empirical implementation of the investment demand model (5.17). Since this model includes the lagged dependent variable in its right-hand side, i.e. the model is dynamic, we need to consider its initial conditions. To this end, we will model the first observations of the endogenous variables in our survey data as a function of some purely exogenous variables. The first part of the simultaneous equations form (3.6-3.8) of the random-effects model aims exactly at facilitating this modelling and, hence, all three parts will be used in the estimation of the present model.

Observations over a five-year period, 1984-1988, were used for the estimation of the investment equation. Hence, system (3.7) comprises five equations, one for each time period. To those, we add one equation, (3.6), for the initial observations on the dependent variable, i.e. the observation for year 1983. As explanatory variables in this equation we have used the values of actual output level over the period 1982-1988. The correlation of these variables with the initial observations turned out to be high, providing an equation fit for (3.6) almost as high as the fit for the whole system reported below. Among the explanatory variables in the investment equation (5.17), six were regarded to be endogenous. Lagged capital stock, \(K_{i,t-1}\), and unutilised capacity \((1 - CU_{i,t-1})K_{i,t-1}\), include terms that are part of the dependent variable \(I_u\) (cf. \(I_u = K_u - K_{i,t-1}\)). Since, according to the maintained hypothesis, the error terms are temporally dependent, these two explanatory variables are contemporaneously correlated with the error term. The unfilled vacancies variables, \(UNVAC_{i,t-1}\) and \(UNVAC_{i,t-2}\), and the unfulfilled production plans variable, \(QERR_u\), include the terms planned employment level and planned production level, respectively, and thus are correlated with the individual-specific effects that are part of the error term. Finally, the level of cash flow that each firm generates probably depends on the skillfulness of the firm’s management and therefore variable \(CF_u\) cannot be assumed to be uncorrelated with the firms’ individual attributes. As mentioned earlier, for a fixed number of time periods \(T\), consistency in the estimates is retained if the endogenous variables are properly instrumented. Realised output level over the period 1982-1988 was found to be highly correlated with variables \(K_{i,t-1}\) and \((1 - CU_{i,t-1})K_{i,t-1}\), and therefore
was used as their instruments. The same set of instruments turned out to be satisfactorily correlated with variable $CF_a$ also. As there was space for increasing this correlation, however, the cost of capital over the same period was also used as instrument. Variable $Q_{ERR_a}$ was instrumented by changes in actual output and cost of capital. Together they were found to be highly correlated with $Q_{ERR_a}$. The fit of the equations that were used to facilitate the instrumentations was high and on the average quite close to the fit of the whole system reported in subsequent tables.

The unfilled vacancies variables were initially instrumented by the percentage changes in realised output. It turned out, however, that the correlation of the latter with the instrumented variables was very low. In search for more appropriate instruments, two additional sets of instruments were used. The first set comprised percentage changes in realised output and cost of capital, while the second set comprised percentage changes in realised output and changes in realised output. As reported in corresponding tables, adoption of different sets of instruments had certain effects on the estimates of some variables. Not surprisingly, the effects were more pronounced on the estimates of the instrumented variables and on the variables that were used as instruments, i.e. unfilled vacancies, and output and cost of capital, respectively. In particular, the level of output was insignificant when percentage changes of the instruments were used but it was significant when the other two sets of instruments were utilised. The cost of capital variable in first differences was insignificant when the latter two sets were used but it was tolerably significant when the former set was used. The effects of the different sets are even more notable when it comes to the estimates of the unfilled vacancies themselves. Variable $UNVAC_{i,t-1}$ was significant when percentage changes of the instruments were used but it was thoroughly insignificant when the other two sets were utilised.

The dilemma that we now face is which of the three sets of instruments we should accept. Percentage changes in output level can be rejected on the grounds of their low correlation with the instrumented variables. Using either the degree of correlation, or the Wald statistic as a criterion for the selection between the remaining two sets does not take us out of the impasse as their values under the two specifications turned out to be close to each other. We will, nevertheless, choose the percentage changes in output and cost of capital as our preferred set of instruments while bearing in mind the results from the use of the alternative sets. The reason is that if the set with only realised output had been used, then the instruments (and the relevant estimates) would be entirely dependent on the specific functional form of one single variable. Hence, the results presented in the main
text concern the estimation of the model with unfilled vacancies instrumented by percentage changes in actual output and cost of capital, whereas the results based on the other two sets are shown in Tables 5.2.A and 5.2.B in Appendix 5.C to this chapter.

Since there are five equations in system (3.7), there are five values of each of the endogenous variables that must be instrumented. However, variables $UNVAC_{t-1}$ and $UNVAC_{t-2}$ need together only six equations for their instrumentation as they are in effect the same variable but in current and lagged values. Thus, system (3.8) comprises twenty-six equations, and in total we have thirty-two equations in system (3.6-3.8). Cross-equations linear restrictions were imposed in system (3.7), while equation (3.6) and system (3.8) were estimated unrestricted.

The state of technology variable $\mathbb{t}$, gave rise to an identification problem in the model. The problem arose from the fact that in, contrast to the rest of variables, is an aggregate variable which means that it varies through time but remains the same over firms. Thus, in each time period, i.e., in each equation of system (3.7), $\mathbb{t}$ exhibits no variation over firms and hence it is not separable from the intercept of the equation which it enters. A way out of this impasse is to drop $\mathbb{t}$ from the investment demand equation. In order to mitigate the effect of the resulted model misspecification on the estimates of the remaining variables we could let the intercepts of the equations vary, thereby, hopefully, capturing the variation of the technology over time. Indeed, this is what we did. We dropped $\mathbb{t}$ from the specification of the model and let the cross-equation restrictions imposed in system (3.7) to apply to all the coefficients except for the intercepts. The estimates of the intercepts reported subsequently are simply the arithmetic means of the unrestricted estimates of the intercepts in each model.

Similarly with previous models, care must be taken of the fact that some of the explanatory variables in model (5.17) are expressed in relative terms while others in absolute terms. In the former group belong the variables that are measured in the form of indices, i.e. $w_{i,t-2}$, $\Delta w_{i,t-1}$, $\bar{q}_{i,t-2}$, $\Delta \bar{q}_{i,t-1}$, $\rho_{i,t-2}$ and $\Delta \rho_{i,t-1}$, and the unfilled vacancies variables that are expressed in terms of percentage points. In order to obtain meaningful estimates of these variables we normalised the latter by multiplying them with the size of the firm as measured by the average value of each firm's actual output level over the period 1981-1988. The model was then estimated and the estimates of these variables presented in the tables were obtained by dividing the variables with the mean value of the actual output of all firms, or, alternatively, by multiplying the estimates by the same mean value.
## Table 5.2
Estimates of Investment Demand Equation Model, One Lagged Dependent Variable
(Time Period: 1984-1988, Number of Firms in the Sample: 93)

<table>
<thead>
<tr>
<th>Dependent Variable: $I_{it}$</th>
<th>Instruments $(s = 1982-1988)$</th>
<th>Explanatory Variables</th>
<th>Instruments $(s = 1982-1988)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>--------------------------------</td>
<td>------------------------------</td>
<td>-----------------------</td>
<td>------------------------------</td>
</tr>
<tr>
<td>Constant</td>
<td>2496.20</td>
<td>$UNVAC_{t-1}$</td>
<td>-185.00</td>
</tr>
<tr>
<td></td>
<td>(-)</td>
<td>(-1.817)</td>
<td>$\Delta Q_{it}/Q_{i,t-1}$</td>
</tr>
<tr>
<td>$I_{i,t-1}$</td>
<td>0.68</td>
<td>$UNVAC_{t-2}$</td>
<td>17.00</td>
</tr>
<tr>
<td></td>
<td>(41.642)</td>
<td>(0.513)</td>
<td>$\Delta Q_{it}/Q_{i,t-1}$</td>
</tr>
<tr>
<td>$w_{i,t-2}$</td>
<td>268.60</td>
<td>$\Delta p_{i,t-1}$</td>
<td>233.75</td>
</tr>
<tr>
<td></td>
<td>(6.028)</td>
<td>(10.035)</td>
<td>$\Delta Q_{it}/Q_{i,t-1}$</td>
</tr>
<tr>
<td>$Q_{i,t-2}$</td>
<td>-0.008</td>
<td>$CF_{it}$</td>
<td>-0.013</td>
</tr>
<tr>
<td></td>
<td>(-1.244)</td>
<td>(-1.566)</td>
<td>$Q_{it}, \bar{Q}_{it}$</td>
</tr>
<tr>
<td>$\Delta w_{i,t-1}$</td>
<td>-11.90</td>
<td>$Q_{it}, \Delta Q_{it}$</td>
<td>-0.085</td>
</tr>
<tr>
<td></td>
<td>(-0.218)</td>
<td>(-10.260)</td>
<td>$Q_{it}, \Delta Q_{it}$</td>
</tr>
<tr>
<td>$\Delta Q_{i,t-1}$</td>
<td>0.028</td>
<td>$K_{i,t-1}$</td>
<td>-0.022</td>
</tr>
<tr>
<td></td>
<td>(2.891)</td>
<td>(-9.108)</td>
<td>$Q_{it}$</td>
</tr>
<tr>
<td>$\Delta \bar{Q}_{i,t-1}$</td>
<td>-285.60</td>
<td>$(1-\mu)K_{i,t-1}$</td>
<td>-0.040</td>
</tr>
<tr>
<td></td>
<td>(-1.868)</td>
<td>(-5.456)</td>
<td>$Q_{it}$</td>
</tr>
<tr>
<td>$\bar{R}^2$</td>
<td>0.90</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wald test</td>
<td>23.32</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$T^*$</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Initial Value Instruments $(s = 1982-1988)$</td>
<td>$Q_{it}$</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(Table 5.2 continues)
The results from the empirical implementation of model (5.17) are given in Table 5.2. The coefficient of the lagged dependent variable is highly significant and less than one in absolute value, which implies that the investment process described by the model is stationary. This result also confirms our assertion, based on previous empirical results, that the firms' expectations are generated by mechanisms that have moving-average error terms of, at least, order one.

The assertion that the firms' expectations are non-static is supported by the data in the case of three out of four explanatory variables. Although changes in labour cost turned out to be insignificant, changes in output, the cost of capital and the price of output were found to be significant. The data provided support to the additional explanatory variables that entered the investment function through the augmented expectations formation mechanisms. So, the price of output and the unfilled vacancies (though only those lagged once) were found to be significant. However, the coefficient of the latter turned out to be negative indicating a probable direct effect on investment expenditure rather than an indirect one through the labour cost expectations formation process. The results with respect to the estimates of the rest of the variables were mostly as anticipated while the fit of the model was found to be very high ($R^2 = 0.90$). The value of the Wald statistic for the null hypothesis of correct model specification turned out to be equal to 23.32 with critical value for $T^* = 5$ at the 5 per cent significance level equal to 22.32.

Although the null hypothesis is very close to be accepted, an attempt was made to improve the specification of the model by increasing the order of the moving average part of the expectations formation mechanisms by one. This amounts to adding the twice-lagged dependent variable in the right-hand side of equation (5.17). In order to undertake the estimation of this specification, we need to model both lagged dependent variables in terms of purely exogenous variables. In other words, we need two initial conditions equations: one for the observations in year 1983 and one for the observations in year 1982. In terms of system (3.6)-(3.8) this amounts to increasing part (3.6) by one equation, while the rest
of the system remains unaltered. Realised output levels were used as explanatory variables in both initial conditions equations. The results from the estimation are given in Table 5.3. The estimate of the twice-lagged dependent variable was very low and insignificant. In addition, the estimate of the change in the cost of capital and the lagged unfilled vacancies declined notably, while the cash flow variable became now significant. The Wald statistic did not improve its value, however. In the light of this result and the fact that the twice-lagged dependent variable turned out to be insignificant, we have no reason to accept the new model specification.
Table 5.3
Estimates of Investment Demand Equation Model, Two Lagged Dependent Variables
(Time Period: 1984-1988, Number of Firms in the Sample: 93)

<table>
<thead>
<tr>
<th>Dependent Variable: ( I_{it} )</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Explanatory Variables</strong></td>
<td><strong>Instruments</strong></td>
<td><strong>Explanatory Variables</strong></td>
<td><strong>Instruments</strong></td>
<td></td>
</tr>
<tr>
<td>( I_{i,t-1} )</td>
<td>( \text{UNVAC}_{i,t-1} )</td>
<td>( I_{i,t-2} )</td>
<td>( \text{UNVAC}_{i,t-2} )</td>
<td></td>
</tr>
<tr>
<td>0.70</td>
<td>-85.00</td>
<td>-0.035</td>
<td>17.00</td>
<td></td>
</tr>
<tr>
<td>(31.048)</td>
<td>(-1.489)</td>
<td>(-1.448)</td>
<td>(0.514)</td>
<td></td>
</tr>
<tr>
<td>( w_{i,t-2} )</td>
<td>( P_{i,t-2} )</td>
<td>( Q_{i,t-2} )</td>
<td>( \Delta P_{i,t-1} )</td>
<td></td>
</tr>
<tr>
<td>259.25</td>
<td>213.35</td>
<td>-0.007</td>
<td>266.90</td>
<td></td>
</tr>
<tr>
<td>(5.922)</td>
<td>(9.238)</td>
<td>(-1.139)</td>
<td>(8.366)</td>
<td></td>
</tr>
<tr>
<td>( \bar{q}_{i,t-2} )</td>
<td>( CF_{it} )</td>
<td>( \Delta w_{i,t-1} )</td>
<td>( Q_{-ERR}_{it} )</td>
<td></td>
</tr>
<tr>
<td>-1378.70</td>
<td>-0.010</td>
<td>-25.50</td>
<td>-0.09</td>
<td></td>
</tr>
<tr>
<td>(-5.451)</td>
<td>(-2.065)</td>
<td>(-0.478)</td>
<td>(-10.350)</td>
<td></td>
</tr>
<tr>
<td>( \Delta Q_{i,t-1} )</td>
<td>( K_{i,t-1} )</td>
<td>( \Delta \bar{q}_{i,t-1} )</td>
<td>( (1 - CU)K_{i,t-1} )</td>
<td></td>
</tr>
<tr>
<td>0.028</td>
<td>-0.023</td>
<td>-85.00</td>
<td>-0.040</td>
<td></td>
</tr>
<tr>
<td>(2.907)</td>
<td>(-8.567)</td>
<td>(-1.245)</td>
<td>(-5.595)</td>
<td></td>
</tr>
</tbody>
</table>

\( R^2 \) | 0.89 |
\( \text{Wald test} \) | 23.10 |
\( T^* \) | 5 |

(Table 5.3 continues)
5.4.3 Interpretation of the Estimated Investment Model

Since the data provided, in general, support to the specification of the investment demand model the results of which are presented in Table 5.2, we will proceed now with the interpretation of that model. In next section we compare our results with those obtained in other studies.

The estimated investment demand model captures several economic conditions that prevailed in Sweden over the greater part of the 1980s, and which were expected to have an effect on the country’s real capital formation. As seen in Chapter 2, during the recovery period 1984-88, real earnings for employees in Swedish manufacturing increased following a period of decreasing earnings during the recessionary years 1980-83. Also, over the second half of the 1980s, the Swedish labour market suffered from a high shortage of skilled labour. The evidence offered by the data indicates that these two conditions in the Swedish labour market had an opposite effect on investment during this period. On the one hand, the increased labour cost stimulated investment expenditure as firms moved towards more capital-intensive production processes in their attempt to reduce the cost of labour. On the other hand, the lack of labour seems to have had a discouraging effect: while the lack of unskilled labour may have had an accelerating effect on investment outlays, it was the high shortage of skilled labour and its important role in the operation of capital-intensive production processes that probably dominated in the firms’ investment decision. Notice, however, that this result was not robust to the different sets of instruments used for the unfilled vacancies variables. Indeed, the latter were found to have no effect on investment when the two alternative sets of instruments were used (see the tables in Appendix 5.C).

The evidence provided by the data on the effect of the conditions prevailing in the Swedish (and foreign) financial markets on capital formation is rather gloomy. The high real interest rates over the greater part of the 1980s resulted in a slow-down in investment spending. The reason is obviously that the rate of return from many new investment projects
did not exceed the cost of financing these projects by means of externally provided funds. In this case, one would expect that the ‘cheaper’ internally generated funds, e.g. the firms’ cash flow, would be a good substitute for the expensive external financing of the 1980s. Yet, the cash flow variable didn’t show to have any significant, let alone positive, effect on investment expenditure. Bearing in mind the fact that period which we study was a period of recovery and that firms were generating high cash flow, one is tempted to conclude that the cash flow was primarily invested in financial assets offering high returns rather than in real assets which became relatively low-return assets due to high market interest rates. In other words, these rates contributed to a redistribution of the two kinds of assets in the total in favour of financial assets. To the extent that this assertion is correct, it could explain the development of firms’ investment in financial assets over the 1980s shown in Figure 2.1 of Chapter 2.

The data provided support to the accelerator principle as the significant effect on investment of changes in output reveals. This is hardly an unexpected result particularly when one bears in mind the fact that the second part of the 1980s was a recovery period. The effect of the price of output must be seen in relation to the output-accelerator effect. Its significant and positive coefficient indicates the stimulating effect it has on investment as it encourages firms to increase their output.

The data provided support for the two modification terms of the investment model. Despite the low unutilised capacity in Sweden during the 1980s as compared to the rest of the industrialised countries, the relevant variable in the estimated investment function indicated a negative effect on investment expenditure. The same is true of the second modification term, the currently revealed unfulfilled output plan. The effect of the latter was negative indicating that a lower-than-planned output level results in a slow-down of investment spending. Thus, the data provided evidence in support of the argument that there is some scope for firms to revise current investment plans in the light of current events such as errors in output plans. Both effects should be seen as an attempt from the firms to correct their current and past expectations errors and adjust the level of their actual capital stock towards its optimal level as it is determined by the actual values of capital stock determinants.

There are no peculiarities in the dynamics of the investment process described by the estimated investment model. The sign of the estimates of $\Delta q_{t,-1}$ and $\Delta p_{t,-1}$ are the same.
with the sign of the (significant) estimates of the corresponding level variables, implying that there is no reversal in the effect of these factors in the short-run as compared to the long-run.

The two-year long-run effects (or rather the medium-run effects) can be obtained from the long-run representation of the estimated investment model which can be written as follows:\(^28\):

\[(1 - 0.68 + 0.022)I = 2496.20 + 268.60w - 1428.00q - 85.00UNVAC + 233.75p - 0.085Q_{ERR} - 0.04(1 - CU)K - 0.022K.\]

Rewriting we obtain:

\[I = 7298.83 + 785.38w - 4175.44q - 248.54UNVAC + 683.48p - 0.25Q_{ERR} - 0.12(1 - CU)K - 0.064K.\]

In order to be able to assess the relative importance of each individual determinant of investment it is instructive to calculate their elasticities. However, since real net investment over the sample period happened to be low and close to zero, it would not be appropriate to calculate the elasticities with respect to the mean value of \(I\); small changes in the latter would imply substantial changes in the values of the elasticities including the likely shift of their sign. An alternative measure of elasticity, suitable for the present purpose, is that based on the mean value of the real capital stock \(K\). Noticing that, in effect, \(\partial I/\partial x = \partial K/\partial x\), where \(x\) is a determinant of investment, the elasticities can be calculated according to the following formula:

---

\(^{28}\) It might be of interest to speculate whether some of the variables are going to vanish in the long-run and therefore should be excluded from the long-run solution of the model. Two such candidates are the currently revealed unfulfilled output plans and unutilised capacity. Both variables are the result of some errors made by the firms when forming their expectations. Although firms continuously learn about the way the economic system functions, our assumption of bounded rationality implies that the learning process is not perfect. Thus, we would expect that firms never stop making errors and therefore the two variables should not vanish in the long-run.
\[ \eta_x = \frac{\partial x}{\partial \bar{K}} \bar{x} \]  
\[ (5.19) \]

where the bar above the variables indicates their mean value over the sample period.

Using the coefficients of the short-run effects in Table 5.2 and the coefficients of the long-run effects from the solution given above, the elasticities can be calculated from formula (5.19). Hence, the elasticity of capital with respect to changes in output (the output-accelerator effect) turned out to be equal to 0.028. The elasticity of capital with respect to changes in the user cost of capital (the short-run effect) was equal to -0.005. Considerably higher was the elasticity with respect to the level of the capital cost (the long-run effect) which turned out to be equal to -0.071. The labour cost elasticity of capital was equal to 0.094 which turned out to be the highest of all the elasticities. The second labour market condition which was found to affect investment, the unfilled vacancies had a much lower elasticity: -0.00012. Thus, the positive effect of labour cost on investment spending dominated by far the negative effect of unfilled vacancies over the period. The elasticity of the change in the price of output turned out to be equal to 0.034 while the elasticity of the level of the same variable was equal to 0.086. Finally, the elasticity of currently revealed unfulfilled output plans turned out to be low and equal to -0.0001, while markedly higher was the elasticity of unused capacity which was found to equal -0.01.

5.4.4 Comparison with Other studies

As a means of evaluating our results it is of interest to compare them with results obtained in other studies. The task is rather imposing, however, since there is a wide variety of investment demand models in the literature that differ with respect to model specification as well as to the specification of the dependent and the explanatory variables. Thus, while it is obvious whether the data do or do not provide support to particular determinants in different models, a comparison of the magnitudes of the effect of these determinants across models (e.g. in terms of elasticities) is not always possible.

Most empirical studies based on the flexible accelerator approach investigate the effect of some particular determinants on investment expenditures. By far the most popular ones are the two neoclassical candidate determinants, namely the output-accelerator effect and the effect of the user cost of capital. The latter usually appears either as such (Ford
and Poret (1990), Bean (1981)), or as a ratio to the labour cost (Catinat et al. (1987), Mato (1989)). The effect of the firm's financial position is usually captured either by the firm's cash flow (Fazzari et al. (1988)), or by some measure of the firm's profit (Ford and Poret (1990), Mato (1989)). Finally, the effect of the degree of capacity utilisation has been investigated either by incorporating this variable in the investment function and letting it affect investment directly (Bean (1981)), or by using it to adjust the effect of other determinants in which case its effect on investment is only indirect (Bergström (1986)).

The dynamic specification of the investment process varies also across models. In a part of them, the functional form of the empirical investment equation coincides with the theoretical one. Hence, the purpose of the empirical analysis for this kind of models is to investigate whether the data support the theory and the theoretical specification of the investment equation. In other studies, however, the empirical specification of the model is allowed to deviate from the theoretical one, with the final form of the investment equation being determined by resorting to the data (Mato (1989), Bean (1981)). Obviously, our model belongs to that class of models.

Among the estimated effects of the determinants considered in our model, those of the output accelerator, the cost of capital, the cash flow and the unused capacity can be compared with the estimated effects in other studies since these are among the most frequently used determinants. The effects of factors corresponding to our unfilled vacancies and output price are not readily available in other studies since they entered our model through the augmented expectations formation mechanisms. Also, as expectations errors are not considered to affect investment, the effect of our unfulfilled output plans variable cannot be evaluated.

We will primarily focus on the results from two studies curried out by Ford and Poret (1990), and Catinat et al. (1987), since the estimated capital elasticities are readily available29. The first study was conducted on semi-annual data (1968:1-1988:11) from the major

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29 Ford and Poret (1990) estimate a great number of investment demand models classified in two groups. In the first group the dependent variable is the capital stock differenced once, and in the second group the same variable is differenced twice (both the dependent and independent variables are logged). As explanatory variables the authors use changes in output, the cost of capital, and the profit rate, as well as different degrees of lag for the dependent variable. We refer to their results from the model with the dependent variable differenced once and the explanatory variables lagged once as this specification is the appropriate for the comparison we curvy out.

Catinat et al. (1987) derive the investment demand function from the cost minimisation problem of the firm. In the empirical implementation, the dependent variable is the ratio of real gross investment to the stock of
seven industrialised economies\textsuperscript{30}, whereas the second one was based on annual data (1972-1983) from four European countries\textsuperscript{31}. The evidence on the accelerator effect was rather different in the two studies. Ford and Poret found that this effect was significant in the case of the USA, Japan, Germany and the U.K., while it was insignificant for the other three countries. The results turned out to be sensitive to the order of the lagged endogenous variable: adding the twice-lagged or three times lagged endogenous variable resulted in insignificant accelerator effects for all countries except Japan. In the model with one lagged endogenous variable the output elasticities of capital were 0.02 for Germany and the U.K., 0.06 for the U.S.A. and 0.09 for Japan.

The significance of the accelerator and the order of its magnitude was notably different in the second study. The authors found a significant accelerator effect for France, Italy, and the U.K., and insignificant for Germany. The elasticities were, respectively, 0.15, 0.12, and 0.06. Comparison with our result (an elasticity of 0.028) shows that it conforms better to the results obtained in the first study (to the extent that these results can be considered as reliable)\textsuperscript{32}.

It is quite confusing that the order of magnitude of the accelerator effect in the second study turned out to be so high compared to the results from the first study. The recessionary period of the late 1970s and early 1980s covers a great part of the sample period in the study of Catinat et. al. As the degree of capacity utilisation was probably rather low over that period one would expect that a rise in demand could be met with existing capacity. Thus, the accelerator effect should be lower as compared to the Ford and Poret's study which covers a longer period with, on average, higher capacity utilisation\textsuperscript{33}. Our study was based on data from a period of rather high capacity utilisation and probably closer to that capital while the rate of growth of output and capital-to-labour cost ratio, and the rate of profit (in the current period for some countries and in the previous period for some others) are the explanatory variables.

\textsuperscript{30} I.e. USA, Japan, Germany, France, Italy, UK, and Canada.

\textsuperscript{31} Germany, France, Italy, and the U.K.

\textsuperscript{32} Blundell et. al. (1992) investigated the significance of the accelerator effect on investment within the $Q$ approach by incorporating the change in output in the $Q$ equation. The estimation of this equation on the U.K. panel data revealed that changes in output had a negative effect on investment. The authors thus conclude that the data do not appear to support an accelerator effect.

\textsuperscript{33} Of course, to some extent the difference in the estimated effects of the accelerator in the two studies may be the result of possible differences in the construction of the variables or of the fact that Catinat et. al. specified the dependent variable as the ratio of gross rather than net investment to the stock of capital.
during the period covered by the sample of Ford and Poret. Therefore, the fact that the
order of magnitude of the accelerator effect in Sweden turned out to be close to those
estimated by these authors, provide some confidence in our results.

There is considerable controversy in the literature as to whether the cost of capital
has any effect on investment or not. While according to the neoclassical investment demand
theory capital spending is driven by prices, some authors have concluded that there is little
or no empirical evidence that the cost of capital affects investment demand (Blanchard
(1986), Gordon and Veitch (1987)).

Ford and Poret found no significant effect of the user cost of capital on investment in
all countries except the U.S.A. which had a scarcely significant capital elasticity with respect
to that variable of -0.005. This value is essentially identical to that based on the results
from our model. In the model estimated by Catinat et al., the cost of capital does not appear
separately but only as a ratio of itself to the cost of labour. Thus, an evaluation of its effect
on investment is not possible. To the extent that it is of interest, we can mention that the
elasticity with respect to this ratio turned out to be insignificant in the case of France and
significant in the case of Germany (-0.02), Italy (-0.01) and the U.K. (-0.003).

Our result that internally generated funds have no effect on investment spending is
in contrast to results usually obtained in the literature. Fazzari et al. (1988) estimated two
investment models based on the sales-accelerator. In the first model, investment was
specified as a function of sales in different lags while in the second model the ratio of sales
to the price of capital entered the investment equation. The estimation was carried out on
U.S.A. panel data which provided support to the effect of the cash flow variable when the
latter was incorporated into the two models.34

The effect of a profit variable on investment has also been studied in the literature.
Two distinct theoretical justifications have been provided for the inclusion of this variable
in the investment model. The first one draws upon the influence of profitability on
investment, while the second one is related to the financing constraint faced by firms in
imperfect capital markets. Under the second interpretation, the role of the profit variable

34 The authors investigated the importance of cash flow within the Q approach also, and found that it
had a significant effect on investment. Similarly, Blundell et al. (1992) in their application of the Q model on
the U.K. panel data found the cash flow to be a significant determinant of investment.
in the investment function is similar to that of the cash flow. There is therefore some scope in looking closer to the empirical performance of the profit variable as a comparison to the cash flow variable in our model.

In the estimated model of Catinat et.al., the rate of profit (defined as gross operating surplus to value added or as value added minus labour and capital costs to the value of capital at replacement cost) turned out to be highly significant in all countries considered. In contrast, Ford and Poret did not find the profits to be significant in any of the investigated countries except Japan. Once again, the results obtained by Catinat et.al., and Ford and Poret diverge, while our results are similar to those obtained by the latter.

Finally, with respect to the free capacity, our result is in accordance to the available evidence in the literature. Bean (1981) found a significant negative effect of free capacity on investment spending in the implementation of an investment model on U.K. data.

5.5 Summary

In this chapter we derived an investment demand function from the cost minimisation problem of the firm under the assumption of increasing costs of adjustment for the quasi-fixed factor capital and non-static expectations with respect to the exogenous variables. The investment decision rule was a function of the firm’s expectations as to the future time paths of the cost of labour and capital, the level of the output and the state of the technology. Upon the substitution of the firm’s expectations formation mechanisms, derived empirically in Chapter 4, in the investment decision rule a closed-form optimal investment model was obtained. This model was subsequently modified by relaxing the perfect capital market hypothesis and by allowing for the effect of the firms’ expectations errors on their investment spending. The modification amounted to including three additional variables in the model: cash flow, currently revealed expectations errors and beginning-of-period unutilised capacity.

In implementing the investment model we commenced by investigating whether currently revealed expectations errors in all exogenous variables had a significant effect on the firms’ investment behaviour. On the presumption that this kind of effect occurs only through the revision of the firms’ investment plans, a regression of expectations errors in the cost of labour, the level of output, and the price of output, was run on the firms’
investment plans revisions. Only unfulfilled output plans turned out to be significant and, therefore, this was the only kind of currently revealed expectations error that was included in the investment function.

The results from the implementation of the investment function provided in general support to the assertion of non-static expectations on the part of the firms. They also provided support to the two additional variables that entered the function through the augmented expectations formation mechanisms although the sign of the unfilled vacancies variable indicated a direct effect on investment rather than an indirect one through the expectational variables. The effects from the rest of the variables turned out to be mostly as anticipated.

Specifically, two labour market conditions in the 1980s were found to have an opposite effect on investment: the cost of labour stimulated, while the high shortage of skilled labour probably discouraged investment spending. In terms of elasticities, however, only the first effect was of a considerable magnitude. The high cost of external financing rendered many investment projects unprofitable. Yet, the "cheaper" internally generated funds, in the form of cash flow, did not contribute to the removal of this cost constraint resulting in a substantial negative effect of the conditions in financial markets on investment expenditures. The data lent support to the output-accelerator as changes in output level showed to have a positive effect on investment. Positive was also the effect of the price of output. Finally, evidence was provided that there is some scope for the firms to adjust their investment spending in the light of unutilised capacity as well as to currently revealed errors in output plans.
Appendix 5.A

We commence the derivation of the investment demand equation by inserting the cost function $G(\cdot)$, as it is given in (5.14), into (5.9) to obtain (we drop the expectation operator symbol during the derivation of the investment function for the sake of convenience; it is, however, put back at the end of the derivation):

$$\min_{I_0} \sum_{j=0}^{\infty} \beta_t^j [\alpha_0 + \alpha_t(t - 1 + j) + \alpha_L w_{t+j} + \alpha_K K_{t-1+j} + \alpha_Q Q_{t+j} +$$

$$0.5[b_{tt}(t - 1 + j)^2 + b_{LL} w_{t+j}^2 + b_{KK} K_{t-1+j}^2 + b_{QQ} Q_{t+j}^2 + b_{LQ} w_{t+j} Q_{t+j} + b_{Lt} w_{t+j} (t - 1 + j) +$$

$$b_{Kt} K_{t-1+j} Q_{t+j} + b_{Qt} K_{t-1+j} (t - 1 + j) + b_{Qt} Q(t - 1 + j) + a_{t+j}(\Delta K_{t+j} + \delta K_{t-1+j})]. \quad (A.1)$$

Differentiating successively (A.1) with respect to $K_{t+j} = 0, 1, 2, \ldots$, and setting equal to zero gives a set of Euler equations:

$$\delta V_0 / \delta K_{t+j} = -\beta_t^{j+1} b_{KK} K_{t-1+j} + \beta_t^{j+1} (b_{KK} + b_{KK}) K_{t+j} + \beta_t^{j+1} b_{KK} K_{t+j} -$$

$$\beta_t^{j+1} b_{KK} K_{t-1+j} + \beta_t^{j+1} b_{LQ} w_{t+j} Q_{t+j} + \beta_t^{j+1} b_{LQ} Q_{t+j} +$$

$$\beta_t^{j+1} b_{Ql} (t - 1 + j) + \beta_t^{j+1} q_{t+j} - \beta_t^{j+1} (1 - \delta) q_{t-1+j} +$$

$$\beta_t^{j+1} a_k = 0. \quad j = 0, 1, 2, \ldots \quad (A.2)$$

Dividing by $-\beta_t^{j+1} b_{KK}$ and rearranging yields:
\[
K_{t+1+j} = \left( 1 + \frac{\beta_t^* b_{KK}}{b_{KK} + \beta_t^*} \right) K_{t+j} + \frac{1}{\beta_t^*} K_{t-1+j}
\]

\[
= \frac{1}{b_{KK}} \left[ b_{tK} w_{t-1+j} + b_{K}Q_{t-1+j} + b_{K}(t+j) + \frac{1}{\beta_t^*} q_{t+j} - (1 - \delta) q_{t+1+j} + d_{t} \right].
\]

Factorising the left-hand side of (A.3) we obtain:

\[
\left[ 1 - \frac{1 + \beta_t^* b_{KK}}{b_{KK} + \beta_t^*} L + \frac{1}{\beta_t^*} L^2 \right] K_{t+1+j}, \quad j = 0, 1, 2, \ldots \quad (A.4)
\]

where \( L \) is the lag operator defined as \( L^n x_t = x_{t-n} \).

The quadratic polynomial (A.4) can be factorised as:

\[
\left[ 1 - \frac{1 + \beta_t^* b_{KK}}{b_{KK} + \beta_t^*} L + \frac{1}{\beta_t^*} L^2 \right] = (1 - \lambda L)(1 - \lambda' L)
\]

\[
= 1 - (\lambda + \lambda') L + \lambda \lambda' L^2.
\]

Equating powers of \( L \) gives:

\[
\lambda \lambda' = \frac{1}{\beta_t^*}, \quad \lambda + \lambda' = \frac{1 + \beta_t^* b_{KK}}{b_{KK} + \beta_t^*}.
\]

We want to determine the magnitudes of \( \lambda \), in particular we need to know whether they are greater or less than unity in value. In order to check this we make the following calculations:

\[
(\lambda - 1)(\lambda' - 1) = \lambda \lambda' - (\lambda + \lambda') + 1 = \frac{1}{\beta_t^*} - \frac{1 + \beta_t^* b_{KK}}{b_{KK} + \beta_t^*} + 1
\]

\[
= -\frac{b_{KK}}{b_{KK}}. \quad (A.7)
\]
From the regularity conditions for the quadratic normalised restricted cost function we know that $\frac{\partial^2 \mathcal{C}(\cdot)}{\partial \lambda^2} = b_{KK} > 0$ and $\frac{\partial^2 \mathcal{C}(\cdot)}{\partial \Delta \lambda^2} = b_{KK} > 0$. Hence, expression (A.7) is negative and therefore one of the $\lambda$s must be greater than unity and the other less than unity. Let $\lambda' > 1$. Rewriting (A.3) using factorisation (A.5) and dividing both sides by $(1 - \lambda' L)$ yields:

$$(1 - \lambda L) K_{t+1+j} = \frac{1}{b_{KK}(1 - \lambda' L)} \left[ b_{LK} w_{t+1+i+j} + b_{LQ} Q_{t+1+i+j} + b_{Kt}(t+j) + \frac{1}{\beta_t} q_{t+i+j} - (1 - \delta) q_{t+1+i+j} + \alpha_k \right] \quad j = 0, 1, 2, \ldots \quad (A.8)$$

Now, rational polynomials such as $1/(1 - \lambda' L)$ in (A.8) are known to give bounded infinite moving sums if they are expanded backwards, when $|\lambda'| < 1$, or forward, when $|\lambda'| \geq 1$ (Sargent (1987), Ch. IX). Since observed changes in capital stock, the left-hand side term in (A.8), are bounded, the right-hand side of (A.8) must also be bounded. From the regularity conditions for $\mathcal{C}(\cdot)$ we know that $\lambda' > 1$. Therefore, for the right-hand side of (A.8) to be bounded, the polynomial $1/(1 - \lambda' L)$ has to be expanded forward in which case we obtain:

$$(1 - \lambda L) K_{t+1+j} = -\frac{1}{b_{KK} \lambda} \sum_{i=1}^{\infty} \left( \frac{1}{\lambda} \right)^i \left[ b_{LK} w_{t+2+i+j} + b_{LQ} Q_{t+2+i+j} + b_{Kt}(t+i+j) + \frac{1}{\beta_t} q_{t+i+j} - (1 - \delta) q_{t+2+i+j} + \alpha_k \right], \quad j = 0, 1, 2, \ldots \quad (A.9)$$

which can also be written as:

$$(1 - \lambda L) K_{t+1+j} = -\frac{1}{b_{KK}} \sum_{i=0}^{\infty} \left( \frac{1}{\lambda} \right)^i \left[ b_{LK} w_{t+1+i+j} + b_{LQ} Q_{t+1+i+j} + b_{Kt}(t+1+i+j) + \frac{1}{\beta_t} q_{t+1+i+j} - (1 - \delta) q_{t+2+i+j} + \alpha_k \right], \quad j = 0, 1, 2, \ldots \quad (A.10)$$
We can now select one equation from expression (A.10) say that for the capital stock at the end of period \( t \), \( K_t \). Recalling our assumption that the firm’s decision made at the beginning of period \( t \) to change its capital stock in the \((t + 1)\)th period is based on information available at the beginning of period \( t \), we specify the expectation operator as \( E_t \) and incorporate it into the investment decision rule which, thus, becomes:

\[
(1 - \lambda L)K_t = -\frac{1}{b_{kk} \lambda^2} \sum_{i=0}^{\infty} \left( \frac{1}{\lambda^2} \right)^i E_t \left[ b_{kK} w_{t+1} + b_{kQ} q_{t+1} + b_{kK}(t + i) + \frac{1}{\beta_t} \left( 1 - \delta \right) q_{t+1} + \alpha_k \right].
\]

(A.11)
Appendix 5.B

The mathematical elaboration of (5.15) is relatively straight-forward when the expectations involved follow autoregressive or moving average processes. In cases where the expectations follow mixed autoregressive-moving average processes the elaboration becomes cumbersome. Here, we will derive the investment demand equation under the assumption that the expectations follow an integrated autoregressive process of the first degree, ARI(1,1). The effect of the moving average part of the processes on the specification of the equation will then be introduced on the basis of theoretical results by Nickell (1985).

5.B.1 Preliminaries

i) Let variable $w_t$ follow a random walk process:

\[ w_t = w_{t-1} + \varepsilon_t, \tag{B.1} \]

where $\varepsilon_t$ is an independent and identically distributed random variable with zero mean and constant variance. The optimal forecast of $w$ at every future time period is equal to the last realisation of the process. Thus, the forecast of $w$ $i$ periods ahead is ($i = 1, 2, ...$):

\[ \hat{w}_{t+i} = w_t. \tag{B.2} \]

ii) Let variable $u_t$ follow an ARI(1,1) process:

\[ \Delta w_t = \phi \Delta w_{t-1} + \varepsilon_t. \tag{B.3} \]

The optimal forecast of $\Delta w$ $i$ periods ahead is given by:

\[ \Delta \hat{w}_{t+i} = \phi^i \Delta w_t. \tag{B.4} \]

Forecasts for $w$ are related to forecasts for $\Delta w$ as follows:
\[ \tilde{w}_{t+i} = w_t + \sum_{j=1}^{i} \Delta \tilde{w}_{t+j} = w_t + \sum_{j=1}^{i} \phi^j \Delta w_t . \quad (B.5) \]

Subtracting \( w_{t-1} \) from both sides we obtain:

\[ \tilde{w}_{t+i} = w_{t-1} + \sum_{j=0}^{i} \phi^j \Delta w_t . \quad (B.6) \]

5.B.2 Derivation of the Investment Demand Equation

The expectations formation processes for the variables of interest can be written as follows (\( i=0,1,2,... \)):

i) Labour Cost:

\[
E (w_{t+1+1} | T_{w,t-1}) = w_{t-2} + \sum_{j=0}^{i+2} \phi^j \Delta w_{t-1} + \\
\alpha_1 UNVAC_t + \alpha_2 UNVAC_{t-2} .
\]

(B.7)

The specification of (B.7) follows from the fact that the autoregressive part of the ARIMA process that drives \( w \) is of order one. Variable \( UNVAC \) is the unfilled vacancies variable, and \( T_{w,t-1} \) is the information set that is relevant for the formation of expectations as to variable \( w \), and which comprises information up to time period \( t-1 \).

ii) Output Level:

\[
E (Q_{t+1+1} | T_{Q,t-1}) = Q_{t-2} + \sum_{j=0}^{i+2} \phi^j \Delta Q_{t-1} + \beta_1 P_{t+1+1} + \\
= Q_{t-2} + \sum_{j=0}^{i+2} \phi^j \Delta Q_{t-1} + \beta_1 P_{t-2} + \beta_1 \sum_{j=0}^{i+2} \phi^j \Delta P_{t-1} ,
\]

(B.8)
where \( \rho^* \) is the planned value of \( p \) which is assumed to follow an ARIMA(1,1,1) process and thus its autoregressive part is an ARI(1,1) process.

iii) User Cost of Capital:

\[
E\left( \widetilde{q}_{t-1,1} \mid T_{q_{t-1}} \right) = \widetilde{q}_{t-2} + \sum_{j=0}^{\ast_2} \phi_j^2 \Delta \widetilde{q}_{t-1}. \tag{B.9}
\]

iv) State of Technology:

\[
E(\{t + i\} \mid T_{t_i}) = t - 1. \tag{B.10}
\]

Expression (B.10) postulates static expectations with respect to technology. This is indicated by the fact that the best forecast of the future time path of technology equals the most recent realisation of the process describing the state of technology.

Inserting expressions (B.7)-(B.10) into the investment decision rule (5.15) yields:

\[
(1 - \lambda L)K_t = -\frac{1}{b_{KK} \lambda} \sum_{t=0}^{\infty} \left( \frac{1}{\lambda} \right)^t \left[ b_{LK} w_{t-2} + b_{LK} \sum_{j=0}^{\ast_2} \phi_j^2 \Delta w_{t-1} + b_{LK} \alpha_1 U N V A C_{t-1} + b_{LK} \alpha_2 U N V A C_{t-2} + b_{KQ} Q_{t-2} + b_{KQ} \sum_{j=0}^{\ast_2} \phi_j^2 \Delta Q_{t-1} + b_{KQ} Q_{t-1} \right] + b_{KL} (t - 1) + \alpha_K].
\]

\[
(\lambda - 1)K_t = -\frac{1}{b_{KK} \lambda} \sum_{t=0}^{\infty} \left( \frac{1}{\lambda} \right)^t \left[ \frac{1}{1 - \lambda^{-1}} w_{t-2} + \frac{1}{\lambda^{-1}} \right] w_{t-2} = -\frac{b_{KL}}{b_{KK}(\lambda - 1)} w_{t-2}
\]

\[
= \frac{(\lambda - 1)}{b_{KK}} b_{KL} w_{t-2}. \tag{B.12}
\]
For variables specified in differences (such as $\Delta w_{t-1}$) we have:

$$- \frac{b_{iK}}{b_{KK}} \sum_{i=0}^{\infty} \left( \frac{1}{\lambda^i} \right) \frac{1}{i} \phi_w^i \Delta w_{t-1} = - \frac{b_{iK}}{b_{KK}} \sum_{i=0}^{\infty} \left( \frac{1}{\lambda^i} \right) \frac{1}{i} \left( 1 - \phi_w^{i+3} \right) \Delta w_{t-1}$$

$$= - \frac{b_{iK}}{b_{KK}} \lambda \frac{1}{1 - \phi_w} \sum_{i=0}^{\infty} \left( \frac{1}{\lambda^i} \right) \left( \Delta w_{t-1} - \phi_w^{i+1} \phi_w^3 \Delta w_{t-1} \right)$$

$$= - \frac{b_{iK}}{b_{KK}} \lambda \frac{1}{1 - \phi_w} \sum_{i=0}^{\infty} \left( \frac{1}{\lambda^i} \right) \phi_w^i \Delta w_{t-1}.$$  

(B.13)

The terms to the left of the sum sign in (B.13) can be written as:

$$\frac{\lambda - 1}{b_{KK}} \frac{1}{1 - \phi_w} b_{iK} \Delta w_{t-1}.$$  

(B.14)

The terms to the right of the sum sign can be written as:

$$\frac{b_{iK}}{b_{KK}} \frac{\phi_w^3}{\lambda \left( 1 - \phi_w \right) \left( 1 - \phi_w^2 \right)} \Delta w_{t-1}.$$  

(B.15)

Multiplying both the numerator and the denominator of (B.15) by $(\lambda - 1)$ by $(\lambda - 1)$ and recalling again expression (A.7) in Appendix 5.A we obtain:

$$- \frac{(\lambda - 1)}{b_{KK}} \frac{\phi_w^3}{(1 - \phi_w) (\lambda - 1 - \phi_w)} b_{iK} \Delta w_{t-1}.$$  

(B.16)

Thus, from (B.14) and (B.16) we see that expression (B.13) now becomes:

$$\frac{(\lambda - 1)}{b_{KK}} \frac{1}{1 - \phi_w} \left( 1 - \frac{\phi_w^2 (\lambda - 1)}{(\lambda - 1 - \phi_w)} \right) b_{iK} \Delta w_{t-1}.$$  

(B.17)

Applying the same manipulations to the rest of variables in (B.11) we end up with the following function:
\[(1 - \lambda L)K_t = \frac{\lambda - 1}{b_{KK}} [b_{LK} w_{t-2} + b_{LW} \Delta w_{t-1} + b_{LK} \alpha_1 U NV AC_{t-1} +
\left(b_{LK} \alpha_2 U NV AC_{t-2} + b_{KQ} Q_{t-2} + b_{KQ} b_{Q^2} \Delta Q_{t-1} + b_{KQ} \beta_1 p_{t-2} +
\left(b_{KQ} \beta_1 b_p \Delta p_{t-1} + \bar{q}_{t-2} + b_{q} \Delta \bar{q}_{t-1} + b_{Kf}(t - 1) + \alpha_K \right)\right].
\] (B.18)

where \(b_i = 1/(1 - \phi_i)[1 - \phi_i^3(\lambda' - 1)/(\lambda' - \phi_i)], \quad i = w, Q, p, q.

Subtracting \(K_{t-1}\) from both sides of (B.18) yields:

\[
\Delta K_t = \frac{\lambda - 1}{b_{KK}} [b_{LK} w_{t-2} + b_{LW} \Delta w_{t-1} + b_{LK} \alpha_1 U NV AC_{t-1} +
\left(b_{LK} \alpha_2 U NV AC_{t-2} + b_{KQ} Q_{t-2} + b_{KQ} b_{Q^2} \Delta Q_{t-1} + b_{KQ} \beta_1 p_{t-2} +
\left(b_{KQ} \beta_1 b_p \Delta p_{t-1} + \bar{q}_{t-2} + b_{q} \Delta \bar{q}_{t-1} + b_{Kf}(t - 1) + \alpha_K \right)\right] + (\lambda - 1)K_{t-1}.
\] (B.19)

As shown by Nickell (1985), moving average errors in the expectations processes generate lagged endogenous variables in the right-hand side of equations such as (B.19). Thus, since we have assumed moving-average errors of order one in the expectations formation processes we end up with the following investment demand equation

\[
\Delta K_t = \alpha_K \Delta K_{t-1} + \frac{\lambda - 1}{b_{KK}} [b_{LK} w_{t-2} + b_{LW} \Delta w_{t-1} +
\left(b_{LK} \alpha_1 U NV AC_{t-1} + b_{LK} \alpha_2 U NV AC_{t-2} + b_{KQ} Q_{t-2} +
\left(b_{KQ} b_{Q^2} \Delta Q_{t-1} + b_{KQ} \beta_1 p_{t-2} + b_{KQ} \beta_1 b_p \Delta p_{t-1} + \bar{q}_{t-2} +
\left(b_{q} \Delta \bar{q}_{t-1} + b_{Kf}(t - 1) + \alpha_K \right)\right)] + (\lambda - 1)K_{t-1}.
\] (B.20)
### Table 5.2.A

**Estimates of Investment Demand Equation Model, Alternative Instrumentation**

*(Time Period: 1984-1988, Number of Firms in the Sample: 93)*

<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>$2080.40$ (43.494)</td>
<td>$UNVAC_{i,t-1}$</td>
<td>$-45.05$ (1.056)</td>
</tr>
<tr>
<td>$I_{i,t-1}$</td>
<td>$0.68$ (-)</td>
<td>$UNVAC_{i,t-2}$</td>
<td>$-19.55$ (-0.616)</td>
</tr>
<tr>
<td>$w_{i,t-2}$</td>
<td>$298.35$ (6.713)</td>
<td>$P_{i,t-2}$</td>
<td>$241.4$ (10.498)</td>
</tr>
<tr>
<td>$Q_{i,t-2}$</td>
<td>$-0.018$ (-2.789)</td>
<td>$\Delta P_{i,t-1}$</td>
<td>$263.50$ (8.161)</td>
</tr>
<tr>
<td>$\bar{q}_{i,t-2}$</td>
<td>$-1084.60$ (-4.472)</td>
<td>$CF_a$</td>
<td>$-0.011$ (1.276)</td>
</tr>
<tr>
<td>$\Delta w_{i,t-1}$</td>
<td>$51.00$ (1.010)</td>
<td>$Q_{ERR_a}$</td>
<td>$-0.081$ (9.726)</td>
</tr>
<tr>
<td>$\Delta Q_{i,t-1}$</td>
<td>$0.020$ (2.030)</td>
<td>$K_{i,t-1}$</td>
<td>$-0.023$ (9.526)</td>
</tr>
<tr>
<td>$\Delta \bar{q}_{i,t-1}$</td>
<td>$-458.15$ (-1.447)</td>
<td>$(1-CU)K_{i,t-1}$</td>
<td>$-0.041$ (5.766)</td>
</tr>
</tbody>
</table>

| $R^2$ | 0.90 |
| Wald test | 22.34 |
| $T^*$ | 5 |

*(Table 5.2.A continues)*

116
(Table 5.2, A concluded)

| Initial Value | Instruments (s = 1982-1988) | $Q_{us}$ |

*Notes:* See the notes of Table 5.2 in the main text.
Table 5.2.B
Estimates of Investment Demand Equation Model,
Alternative Instrumentation
(Time Period: 1984-1988, Number of Firms in the Sample: 93)

Dependent Variable: $I_\alpha$

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>2274.20 (-)</td>
<td>UNVAC, C, $t-1$</td>
<td>3.48 (0.075)</td>
</tr>
<tr>
<td>$I_{t-1}$</td>
<td>0.68 (42.353)</td>
<td>$\Delta Q_{u}/Q_{t-1}$</td>
<td>$\Delta Q_{u}/Q_{t-1}$</td>
</tr>
<tr>
<td>$w_{t-1}$</td>
<td>285.60 (6.277)</td>
<td>$\Delta P_{t-1}$</td>
<td>243.10 (-10.146)</td>
</tr>
<tr>
<td>$Q_{t-2}$</td>
<td>-0.018 (-2.751)</td>
<td>$\Delta Q_{t-1}$</td>
<td>278.80 (8.258)</td>
</tr>
<tr>
<td>$\bar{q}_{t-2}$</td>
<td>-1071.85 (-4.314)</td>
<td>$CF_{t}$</td>
<td>-0.011 (-1.202)</td>
</tr>
<tr>
<td>$\Delta w_{t-1}$</td>
<td>33.15 (0.629)</td>
<td>$Q_{ERR}$</td>
<td>-0.079 (-9.263)</td>
</tr>
<tr>
<td>$\Delta Q_{t-1}$</td>
<td>0.018 (1.889)</td>
<td>$K_{t-1}$</td>
<td>-0.022 (-8.861)</td>
</tr>
<tr>
<td>$\Delta \bar{q}_{t-1}$</td>
<td>-578.00 (-1.747)</td>
<td>$(1-CU)K_{t-1}$</td>
<td>-0.042 (-5.727)</td>
</tr>
</tbody>
</table>

$R^2$ 0.90

Wald test 21.12

$T^*$ 5

Initial Value Instruments $(s = 1982-1988)$ $Q_{t_0}$

Notes: See the notes of Table 5.2 in the main text.
Chapter 6

Discussion

In the empirical analysis carried out in this dissertation we investigated the investment behaviour of Swedish manufacturing firms. To this end, a new data set covering a group of firms was used. The disaggregated form of this data provided the possibility to separate the firms' purely economic behaviour from their non-economic individual attributes. The convenience that data at this level provide, however, has its cost. Panel data analysts usually encounter three kinds of problems not encountered by time-series analysts.

The first problem arises from the fact that some of the participants in the survey choose not to respond to certain questions or decide not to participate in the survey for some (or many) years at all. If the probability to respond hinges on variables that are treated as dependent, then one runs the risk that a selectivity bias may arise in the sample. This risk has been encountered by us during the course of this dissertation since for all dependent variables of our models we had a great number of missing values. On the basis of the informal test that we carried out, however, we concluded that a selectivity bias was not expected to be a serious problem. A difficult situation would have developed if there were reasons to believe that there was a selectivity bias in the sample. Some techniques have been suggested by econometricians and statisticians in the relevant literature to cope with problems due to nonresponse (Manski and McFadden (1981), Amemiya (1985), Maddala (1986)). However, their successful application requires that we know the reasons for nonresponse and that we have observed variables which can be used to explain it. Unfortunately, this is not always the case.

The second problem usually encountered in empirical applications at the disaggregate level is related to the fact that typical panel data comprise a great number of cross-sectional units but observed only over a small number of time periods. An implication of this is that, in dynamic models in particular, the information contained in these observations is not
sufficient to provide consistent estimates of the parameters. This is due to the fact that
dynamic processes are not independent of their past history. Observing the process over
a short period of time is not enough to give a satisfactory picture of its characteristics.

The third problem that panel data analysts encounter hinges on the fact that at the
disaggregate level many explanatory variables are correlated with the error term. The
individual-specific effects in this term quite frequently affect not only the dependent
variable of the model but also some or all of the variables that enter the model as
explanatory variables. While from the estimation point of view this problem is not
intractable, it may be rather imposing when it comes to the identification and instru­
mentation of these variables.

Both of these problems were encountered in the empirical implementations in
previous chapters and were accommodated by the simultaneous equation form of the
error-component model suggested in the literature. The estimation of the error-component
model along the lines of this methodology proved to be rather convenient due to the fact
that it can be facilitated by procedures readily available in standard statistical packages.
However, testing the model specification by means of, e.g. a Wald test, turned out to be
cumbersome. The reason is that one needs to calculate the covariance matrix of the model,
the formidable form of which is given in Appendix 3.B to Chapter 3. To our knowledge,
no standard statistical package can readily accommodate the calculation of this matrix and
thus one must write one’s own programmes. Since this is an imposing task many panel data
analysts may be discouraged from using this methodology which is, otherwise, convenient
and rapidly developing (Hausman, Newey and Taylor (1987), Arellano (1989a, 1989b,
1990), Rothenberg and Ruud (1990)). Therefore, it is maybe worth mentioning the results
from our experimentation with an alternative form of this covariance matrix.

The form of the covariance matrix of the 3SLS residuals given in Appendix 3.B is the
form which applies when one imposes the restriction that the intercepts of the equations
that constitute the system are all equal to each other. This is how it should be in the
estimation of the error-component model in a simultaneous equation form. In this case
there are three additive parts within the square brackets of the matrix. If the equality
restriction is not imposed on the intercepts, then the last two terms drop out (Bhargava
(1987)). In that case the calculation of the value of the matrix becomes considerably easier,
and one can wonder about the effect on the accuracy of diagnostic tests of the use of the
shorter form of that matrix while retaining the restriction of the equality of intercepts
during the estimation. The value of the Wald statistic was calculated for both forms of the
covariance matrix and for all models estimated in previous chapters. The differences in
the Wald statistics due to the different covariance forms were infinitesimal. This is true
both of models for which the dependent variable was in first differences and in levels.
Hence, while the form of the covariance matrix given in Appendix 3.B is the appropriate
one when the restriction of the equality of intercepts is imposed, the results provided from
the use of this matrix seem to be very well approximated by those obtained from the
utilisation of its shorter variant.

In previous chapters of this dissertation we presented the results from the empirical
implementation of different expectations formation mechanisms and of an investment
demand model. With respect to the first, one can make two comments. The first comment
pertains to the inability of the diagnostic test to discriminate among the three purely
extrapolative models: the first- and second-order adaptive model, and Frenkel's
error-correction model. As mentioned in Chapter 4, an explanation for that could be found
in the fact that the omitted variables from, say, the first-order adaptive model as compared
to the second-order adaptive model or Frenkel's model have weak trends (or no trends at
all) and therefore it is difficult to detect by the diagnostic test. The issue could have been
left here if it wasn't for the different behavioural characteristics that these models assign
to the agents and their different implications for the functional forms of the decision rules
which they enter; in our case case the investment function. How can one cope with this
problem? If the inability of the test to detect the omitted variables depends on their weak
trends, then one could hope for panel data with a greater number of observations.
Alternatively, one could estimate the expectations formation mechanisms in their unre­
stricted form, i.e. with the expectation of the variable as a distributed lag on past realisa­
tions, and test the validity of the restrictions which give rise to the different specifications
of the expectations adjustment models.

The empirical implementation of the augmented extrapolative models revealed that
economic agents probably utilise a greater amount of information when they form
expectations than is usually assumed in the modelling of economic behaviour. Results from
other fields of economics can be of considerable assistance in determining the variables
to be included in the agents information set. The literature on wage cost determination
was of significant importance for the specification of the labour cost expectations formation
process in a previous chapter.
The results from the implementation of the investment demand function also provided evidence in support for the hypothesis of augmented information sets. One should, however, be prepared to encounter some unanticipated effects of the additional explanatory variables on the dependent variable. In our case, an unexpected effect came from the unfilled vacancies variable. Its sign indicated a direct effect on investment rather than an indirect one through the expectations formation mechanism for the labour cost. The presence of such direct effects may lead to some difficult interpretation problems. While theory provides the justification for the inclusion of some variables in the expectations formation mechanism and probably predicts the sign of their parameters, if these parameters turn out to have the opposite sign in the final behavioural model their interpretation may not be at all obvious. In our case, the sign of the price of output retained in the estimated investment function the sign it had in the estimated expectations formation process. The unfilled vacancies variable, however, did not. Nevertheless, an interpretation was provided by resorting to the facts.

The assumption of boundedly rational agents was made both in the analysis of the firms' expectations formation and of their investment spending. The inclusion of expectations errors in the investment function was supported by the data. That came as no surprise to us given the complex and continuously changing economic environment with the imposing, almost intractable, task for the firms to update sufficiently their information set. However, as indicated by the elasticities of the currently revealed unfulfilled output plans and the unutilised capacity, the firms more often take their errors into account when they plan for their investment spending than when the plans are completed and therefore must be revised.

With respect to the three most usual explanatory variables in neoclassical investment models, the results were not in accordance with those usually obtained in the empirical literature. The cash flow variable had no significant effect on investment although the cost of external financing was very high during the 1980s. In an attempt to provide an explanation for this, we speculated that cash flow was primarily invested in financial assets offering high returns rather than in real assets which became relatively low-return assets due to high market interest rates. The result was, thus, a redistribution of the two kinds of assets in the total in favour of financial assets. Although this seems to be a rational reaction on the part of firms, one might wonder about its implications for the competitiveness of the firms in the future.
Finally, in accordance with the prediction of the neoclassical investment theory the data provided evidence in support for a significant effect of the user cost of capital on the firms' capital formation. And contrary to that theory but in accordance with our assumption, a significant effect from the output on investment was indicated.
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