TECHNICAL CHANGE IN CANADIAN MANUFACTURING:

A REGIONAL ANALYSIS

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A REGIONAL ANALYSIS

by

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ABSTRACT

The rate of profit in Canadian manufacturing fell by almost 37% between 1955 and 1984. Throughout much of this period, the reduction in profitability was accompanied by increasing unemployment of both capital and labour and by a deceleration of economic growth. The impact of this crisis on Canadian regions was markedly uneven.

This thesis explains the crisis and its uneven spatial impact using the Marxist theory of the falling rate of profit. There are two stages to this analysis. Firstly, the relationship between technical change and accumulation is examined using a two-department model of the economy. Secondly, the effect of various types of technical change on regional manufacturing performance in Canada is evaluated.

The theoretical analysis provides the analytical support required by the theory of the falling rate of profit. In particular it shows that viable, labour-saving technical change may cause the aggregate rate of profit in an economy to fall, and it provides a model of the likely direction of technical change that affirms the importance of labour-saving bias in innovation.

A Marxist accounting framework is outlined that clarifies the relationship between the labour-value of commodities and their respective prices. Using this accounting framework a set of measures of technical change and economic performance are provided in both value and price terms. These measures are estimated for selected industries in six

Canadian regions.

The empirical analysis confirms the theoretical arguments, showing that labour-saving technical change exerted a negative effect on the rate of profit in all regions. The data also reveal that regional variations in economic performance are marked, both at the level of manufacturing as a whole and at the industry level. Little support was found for the "industry-mix" explanation of regional fortunes and the neoclassical arguments of regional convergence.

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TABLE OF CONTENTS

APPENDICES

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

The rate of profit in the Canadian manufacturing sector fell by 37% between 1955 and 1984. As the rate of profit declined, so the rate of growth of real manufacturing output decreased from an annual average rate of nearly 6% between 1955 and 1974 to an average annual growth rate of less than 1% between 1979 and 1984. Over the same period the unemployment of both capital and labour has increased: capacity utilisation rates falling dramatically through the 1970s and production hours worked in manufacturing decreasing by almost 2% per year between 1979 and 1984. Those workers fortunate to retain their jobs have seen the purchasing power of their wages slowly eroded with real wage levels declining after 1977. The Canadian manufacturing sector, like that of the United States and many West European nations (see Lipietz, 1986; Reati, 1986 and Wolff, 1986) appears to be in a crisis.

To what extent however do these aggregate figures belie significant spatial and sectoral variations in measures of economic performance? Rigby (1987) has shown that the textile industry in Canada has performed much better than average, experiencing a marked upturn in its rate of profit since the mid-1960s. Webber and Tonkin (1987) also show that although the Canadian food and beverage industry exhibits a history broadly similar to the manufacturing average, that sector differs in a number of important respects and in general performs better than the manufacturing sector as a whole over the post-war period.

The downturn in profitability, decrease in capacity utilisation and reduction in the size of the manufacturing workforce is not only sector-specific, it is also concentrated in space. While manufacturing employment in Canada declined by approximately 9% between 1979 and 1984, it fell by over 22% in British Columbia, by nearly 17% in the Atlantic Provinces and by only 3.5% in Ontario. The reduction in levels of capacity utilisation was similarly uneven geographically; falling by over 50% in the Atlantic Provinces over the study period and by only about 20% in Ontario. Although certain regions such as Alberta exhibit patterns of short-term growth and recession unique within the Canadian manufacturing system over the post-war period, no region has been able to withstand the gradual decrease in profit rates that has characterised the Canadian manufacturing economy as a whole since 1950.

Various explanations for the demise of manufacturing industries in developed nations have been proposed. Whether these stress the reduction in levels of innovative activity (Mensch, 1979), overcapacity and the gradual obsolescence of fixed capital (Forrester, 1981), input price shocks (Bruno and Sachs, 1982) or declining levels of productivity (Berndt, 1980 and Wolff, 1986), all are shown to be wanting in certain respects (see Shaikh, 1983). Most importantly, these arguments divorce the explanation of economic crisis from factors endogenous to capitalist economies. It is not the aim of this thesis to evaluate these competing claims. Rather, it is accepted that Marxist arguments about the falling rate of profit provide a better explanation for the contemporary crisis of industrial capitalism than those outlined above. These arguments do however contain a number of inconsistencies.

In essence the Marxist model asserts that the struggle between capitalists and workers over the distribution of the value added in production compels capitalists to adopt labour-saving methods of production in attempts to reduce the bargaining strength of labour. However, this form of technical change reduces the very basis of profit, that is the exploitation of labour in production, and consequently the rate of profit falls precipitating a crisis (Marx, 1967 and Shaikh, 1978).

This logic, at least as represented in the writings of contemporary Marxists, has several deficiencies. Firstly, it does not clarify why firms will introduce new techniques of production if they reduce the rate of profit. Secondly, Okishio (1961) has proven, that cost-reducing technical changes cannot reduce the rate of profit under certain conditions. Van Parijs (1980) claims that Okishio's theorem is robust and that it effectively negates the argument about the falling rate of profit. This work has exerted a profound disquiet among Marxist scholars. Thirdly, it is not clear how technical change itself affects commodity prices and measures of economic performance, including the rate of profit. Fourthly, persistent troubles with the relationship between values and prices, the so-called transformation problem, cloud the relationship between variables measured in value terms and those measured in price terms (see Steedman, 1977 and 1981). This problem is particularly acute for arguments about the falling rate of profit and capitalist competition, which make use of both value and price categories, and of course for the measurement of Marxist value categories in general. Fifthly, while the theory of the falling rate of profit provides an explanation of economic crisis in capitalist economies, it does not assert that all industries and all regions will experience the same crisis of profitability. The bases for regional competition are not clear in the Marxist model and there has been almost no empirical work to examine the effects of technical changes on the fortunes of particular regions.

The aim of this thesis is to examine some aspects of the relationship between technical change and accumulation in order to determine more clearly the direction taken by technical changes and the effects of those changes on profitability and economic growth. Both theoretical and empirical analysis are employed to achieve this aim.

The thesis is comprised of six substantive chapters and a conclusion that follow this introduction. Chapter 2, provides a selective review of the literature on the topic of technical change, economic crisis, industrial and regional restructuring. After presenting a brief overview of the geography of uneven development, this chapter critically examines a variety of explanations of regional growth and decline. The theories examined are found to be deficient in several respects. It is argued in this chapter that while the Marxist theory of the falling rate of profit best captures the dynamic of industrial evolution, the determinants of movements in that rate are not clear. The effects of technical change on regional fortunes are also vague in the Marxist literature. These shortcomings provide the rationale for much of the following work in the thesis.

Chapter 3 addresses the relationship between commodity values and their respective prices. After generalising the conditions under which commodity values can be measured, the chapter argues after Farjoun and Machover (1983) that the transformation issue is misguided. An alternative accounting framework is proposed that develops the concept of expected prices. These prices are shown to be determined up to a probability distribution by commodity values. A set of measures of economic performance are then provided in both value and (expected) price terms. The bases for inter-firm, inter-industry and inter-regional competition are outlined in this chapter.

In Chapter 4, traditional Marxist models of accumulation without technical change are examined. Those models are shown to be limited by a rigid set of assumptions. A more flexible two department model of accumulation is then outlined. This model shows that a golden-age growth path exists for the economy and that in the absence of technical change there is no long-run tendency for the rate of profit to fall and crises to develop.

In Chapter 5, the theory of the falling rate of profit is reviewed. That work is shown to be unable of specifying whether or not labour-saving technical changes will cause the rate of profit to rise or fall. The effects of technical changes of various sorts on commodity values (and hence expected prices), the rate of exploitation and the rate of profit are then examined. This work is novel in the sense that it relaxes the assumptions which limit the findings of Okishio. This chapter shows that certain types of viable labour-saving technical changes may indeed cause the rate of profit to fall. The chapter thus reasserts the efficacy of the theory of the falling rate of profit as an explanation of crisis in capitalist economies.

While Chapter 5 shows that labour-saving technical changes may cause the rate of profit to fall, it remains unclear why technological progress should exhibit a labour-saving bias. Chapter 6 reviews the literature on induced innovation and bias in technical change. Building on this work a simple probabilistic model is outlined that shows how relative factor prices determine the bias in innovation. Empirical evidence from the Canadian manufacturing sector provides general support for this model.

Chapters 5 and 6 outline the logic of a model of capitalist competition and technical change. While this theory asserts that periodic reductions in profitability are inevitable, it does not demand that all firms, all industries or all regions must suffer the same crisis of profitability. Chapter 7 builds on the regional dimensions of this work outlined in Chapters 2 and 3 and provides an empirical examination of the effects of technical change on various measures of economic performance in the Canadian manufacturing sector over the post-war period. Both sectoral and regional variations of the effects of technical change are examined.

Chapter 8 concludes the thesis summarising the main results of the theoretical and empirical investigation. The thesis contributes to the literature on technical change and economic growth. It shows that labour-saving technical changes can decrease the aggregate rate of profit in an economy and it provides a rationale for labour-saving bias in technical change. Empirical analysis confirms the validity of the Marxist theory of the falling rate of profit and shows how regions compete for profits both in production and in the market. The data also reveal that regional and sectoral variations in economic performance are marked.

CHAPTER 2

LITERATURE REVIEW: TECHNICAL CHANGE, ECONOMIC GROWTH AND CRISIS

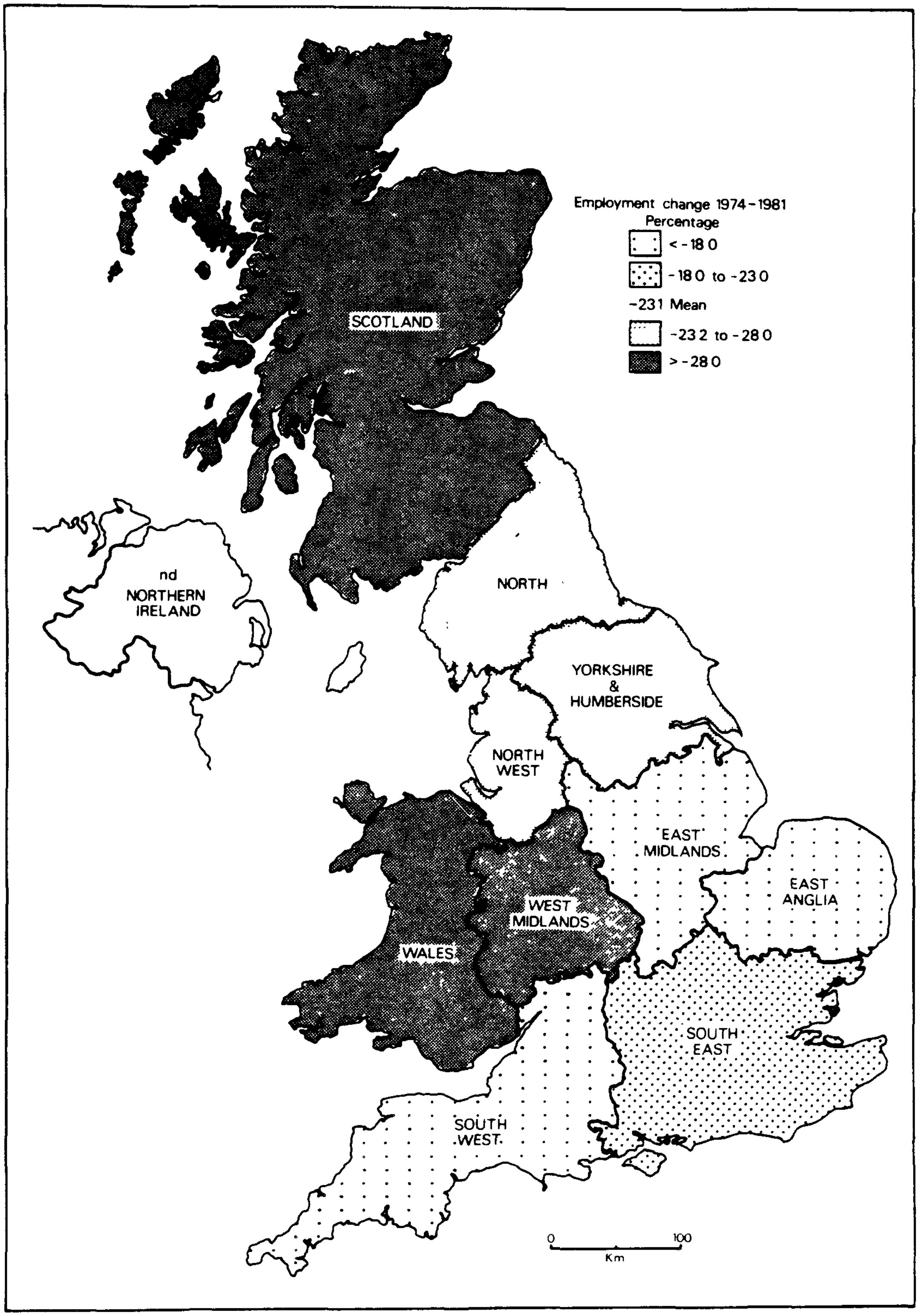
2.1 Introduction

Over the last two or three decades the economies of many developed nations have been characterised by deindustrialisation, by decline in the relative and absolute significance of manufacturing activities (Bluestone and Harrison, 1982 and Massey and Meegan, 1982). In West Germany for instance, manufacturing profitability fell by approximately 60% between 1960 and 1981 (Reati, 1986). This reduction in profitability was accompanied by a marked reduction in employment: the number of manufacturing jobs in West Germany decreasing by 1.3 million or by some 14% between 1972 and 1982 (Watts, 1987). In Canada too, between 1950 and 1981, the rate of profit in manufacturing fell by approximately 40% (Webber and Rigby, 1986). While manufacturing employment increased in Canada over much of this period, it fell dramatically in the mid-1970s along with capacity utilisation rates as manufacturing growth plumetted. In the U.S. and France, the rate of profit has also fallen sharply since 1950 (see Wolff, 1986 and Lipietz, 1986), though the impact on employment has not been as severe in these countries as in Britain or West Germany.

Within developed economies, the pattern of manufacturing decline and employment loss have been far from uniform. For example, in Britain between 1972 and 1982 over 2 million (26%) manufacturing jobs were lost, with 1.4 million of these jobs "disappearing" after 1979 (Watts, 1987). However, it would be misleading to claim that if you were employed in the manufacturing sector of Britain at that time, you stood a 1 in 4 chance of losing your job, for spatial variations in the rate of employment loss were dramatic (see Massey and Meegan, 1982 and Watts, 1987). Figure 2.1 shows the regional variations in employment loss in Britain between 1974 and 1981. The most striking feature of this figure is the marked disparity in rates of job retention between the north and west of the country, all regions of which suffered greater than average employment loss (<-23.1%) and the south and east of the country, all regions of which suffered less than average employment loss (>-23.1%). The frostbelt-sunbelt shifts of the U.S. provide another clear example of recent reversals in regional fortunes (see Figure 2.2), with the regions that comprised the traditional manufacturing belt all losing manufacturing jobs between 1967 and 1977 to the fast growing states of the south and west (see Perry and Watkins, 1977). In Canada too, the long period of post-war manufacturing employment growth faltered in the 1970s and stamped an uneven mark over the provinces (see Norcliffe, 1987).

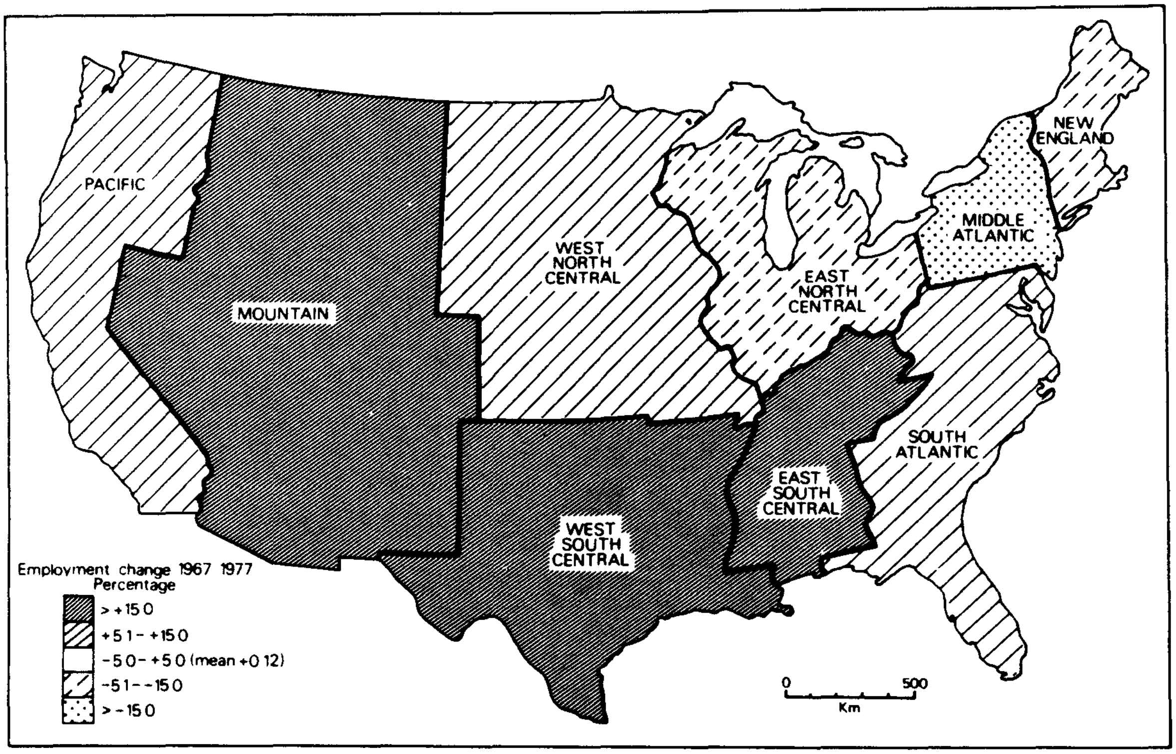
Capital data where available, especially investment series, record similar trends to those identified above. Gertler (1986a) for example, shows that the rate of capital growth in Canada exhibits clear spatial differences. Anderson and Rigby (forthcoming) also show that the average age of capital and its rate of retirement vary markedly between Canadian regions. In the U.S. too, rates of capital formation and the

FIGURE 2.1: MANUFACTURING EMPLOYMENT CHANGE IN BRITISH REGIONS, 1974-1981



Source: Watts (1987)

FIGURE 2.2: MANUFACTURING EMPLOYMENT CHANGE IN U.S. REGIONS, 1967-1977



Source: Watts (1987)

age and productivity of capital vary over space (Varaiya and Wiseman, 1981).

A number of explanations have been proposed to account for the crisis in manufacturing and its regional dimension. Insofar as these divorce the history of manufacturing change from the broader structural forces that shape the form of the capitalist mode of production they are to be rejected. The fortunes of particular regions depend upon the competitive positions of the firms and industries which they comprise. Regional development at all scales must be viewed as the spatial manifestation of the process of capitalist accumulation.

The accumulation of capital by any firm depends on its ability to appropriate surplus from labour in production and from other firms in the market. In the competitive struggle for profit, technical change is assumed to play a crucial role. However, the precise effects of technical changes of various sorts on profitability, inter-firm and inter-industry competition and regional growth are not well understood. This chapter examines a number of theories of technical change, economic growth and regional development, highlighting the strengths and weaknesses of each. It is argued that while Marxist theory can most readily account for the temporal and spatial dynamics of the process of accumulation, that theory still contains a number of unresolved issues

The remainder of this chapter is organised in four sections. In Section 2 the relationship between technical change and economic growth is briefly reviewed. Various explanations of economic crisis are discussed and the Marxist model is shown to have a number of advantages over other models. In Section 3, selective theories of regional development are critically examined in an attempt to account for the uneven impact of growth and recession in capitalist economies. Section 4 briefly examines empirical work in Marxist studies of uneven development and Section 5 concludes the chapter outlining the issues tackled by the present work. The term "region" is used throughout this chapter to denote areas in space that share certain characteristics. These areas are not necessarily contiguous. The focus will be on sub-national units but not necessarily urban areas.

2.2 Technical Change and Economic Growth

The range of explanations proposed to account for the manufacturing decline in developed countries may be divided into two camps. Firstly, there are those that explain the crisis as a consequence of random, exogenous shocks to the economy. Secondly, there are those that see the recession as the result of forces endogenous to capitalist economies. In the first group, Berndt (1980) and Bruno and Sachs (1982) stress the importance of increases in input prices on retarding productivity, wage growth and accumulation. Beenstock (1984) explains the decline as the result of competition from third world producers and Kendrick (1980) attributes the crisis in the U.S. to a wide range of factors that collectively reduced productivity. While not dismissing the importance of these exogenous determinants in contributing to the downturn in manufacturing profitability and growth, they all fail to relate the cause(s) of the crisis to forces emanating from within the capitalist mode of production. Yet, the extent of the crisis and the regular nature of major economic recession (see Mandel, 1975 and van Duijn, 1983) demand explanation beyond appeal to the occurrence of random shocks.

2.2.1 Long Waves of Accumulation

For proponents of the long wave model, the crisis of the late-1970s and early-1980s is seen simply as the downswing of a growth cycle. That capitalist economies are characterised by alternating phases of growth and recession is a view shared by long wave analysts, though there is much disagreement as to what mechanisms drive the cycle and thus what the specific causes of the crisis are. Technological change plays a key role in most of these explanations which are briefly examined here.

Though van Duijn (1983) notes that the Dutch economists van Gelderen and De Wolff were the first to advance the notion of long run cycles of economic development, it was Kondratieff (1935) who was chiefly responsible for popularising the long wave hypothesis. Kondratieff identified long cycles of growth and decline in commodity price indices for England, France and the U.S. between 1780 and 1920. Though his primary contribution to the debate was the presentation of empirical evidence for their existence, Kondratieff did advance arguments to explain the price cycles. He claimed that long waves were driven by the varying availability of investment funds, by movements in interest rates and by the development of large scale fixed capital structures. Thus, the canal and railway building epochs in Britain especially were seen to have ushered in long rounds of economic expansion. Kondratieff provided no explanation of economic downturns.

Rostow (1975) also advances a long wave argument based on a price cycle. He argued that a rise in the price of materials and food increased the costs of production and stimulated demand for new technologies. Rostow identified several "stages of growth" each linked to the development of key propulsive industries such as the cotton-textile industry, the growth of railways and later iron and steel and consumer durables. Growth during each upswing of the cycle was supposed to overshoot the requirements of the economy leading to recession until demand "catches up" with the economy and once more price increases usher in a new round of innovation. Rostow may be criticised for not linking the price cycle more effectively with technical change. In particular the determinants of demand are not made clear and his growth stages appear to be based on the chance development of key sectors of the economy. Marshall (1987) criticises Rostow on empirical grounds, questioning why the energy price increases of the 1970s did not produce an upswing in economic activity.

A second explanation of long waves, and indirectly the crisis in manufacturing, stresses more explicitly the role of technological change in promoting growth. This explanation is based on the work of Schumpeter (1939) and more recently Mensch (1979). Schumpeter argued that innovation is not continuous but rather occurs in distinct clusters, introducing new products and processes of production to the economy and fuelling economic expansion. The lower turning point of the long cycle was explained by Schumpeter to follow "periods of creative destruction" when old technologies were scrapped and the conditions established for new swarms of innovations. Delbeke (1981) criticises Schumpeter for providing no explanation for the regular timing of innovatory periods. Marshall (1987) goes further and claims that for Schumpeter the key to innovation was the personal psyche of entrepreneurs and that he failed to link entrepreneurial activity with broader market forces. Mattick (1981) echoes this criticism.

Mensch (1979) renewed interest in cycles of innovation, presenting empirical evidence of the clustering of "basic innovations". In Mensch's view, peaks of innovatory activity were followed by a "technological stalemate", periods of non-radical technical change based upon improvement and modification during which time economic growth slows as markets are saturated and competition intensifies. This is similar to the product-cycle model of Vernon (1966). During the downturn Mensch surmised that radical inventions occur which are introduced to the economy stimulating renewed growth when returns on existing ventures decrease. Delbeke (1981) criticises Mensch for ignoring the influence of demand on innovation. Freeman et al. (1982) are also critical of Mensch's work. They take issue with his empirical data, finding little correlation between clusters of basic innovations and the depressive phase of the long cycle. Kleinknecht (1981) adopts a similar position, questioning the "depression-trigger" hypothesis of Mensch.

Rather than abandoning the importance of innovation, Freeman et al. (1982) claim that it is not the swarming of separate innovations that is responsible for economic growth, rather it is the interrelationship between certain kinds of innovations that introduce radical new technologies to the economy. van Duijn (1983) supports this thesis linking it with the product-cycle model to produce a series of S-shaped cycles of economic growth, the amplitude of each extended by the process of innovation diffusion. Decline is explained by van Duijn by recourse to Forrester's (1981) model of the over-accumulation of fixed capital. The saturation of markets and intense competition, in line with the product-cycle arguments characterises the depressive stage of the long wave.

In general, supporters of the long wave hypothesis acknowledge the central role of innovation in fuelling the cycle of growth and recession. While it remains unclear whether the clustering of innovations precipitates an upturn in the cycle, or whether innovation follows the upturn, most agree that the introduction of new products and processes of production generate growth and that the diffusion of innovations through an economy sustains that growth. Explanations for economic decline follow the product-cycle model. Increased competition, market saturation and overproduction mark the onset of recession.

As it stands, the long wave model has a number of shortcomings. Firstly, it fails to establish why cycles of development should exhibit a regular periodicity of between 40 and 60 years peak-to-peak. Secondly, precise explanations for the turning points of the cycle are not provided. For example, if the clustering of innovations is responsible for the upturn in the growth cycle, what factors govern their mass introduction to the economy? Thirdly, adherents of the long wave thesis do not link their arguments with a broader theory of economic relations. Long wave arguments must be historically grounded in a theory of capitalist production to be intelligible. Mandel (1975 and 1981) has attempted to make this connection, though Marshall (1987) argues that he is unsuccessful. A rather different interpretation of the relationship between technical change and economic growth is now provided after Marx (1967).

2.2.2 The Marxist Model of Accumulation

According to Marx (1967), the central mechanism that structures relations in capitalist economies is the conflict over the distribution of the value added in production by labour, the source of profit. Capitalists and workers struggle to maximise profits and wages, their respective shares of the value added. In turn, capitalists compete among themselves to attain as large a portion of profits as possible.

Technical change plays a central role in both conflicts. Capitalists compete with one another to a large extent through the introduction of product and process innovations. Technological change is also a powerful weapon in the firm's struggle with labour over the distribution of the value added. It may be used to replace labour directly with machines, thereby reducing the bargaining position of the working class (Weisskopf, 1978), and it can also be used to discipline and enforce the rhythm of work, reduce the autonomy of the labourer and raise productivity (Braverman, 1974 and Burawoy, 1979).

For Marxists, crises are the result of reductions in the rate of profit. Just as adherents of the long wave argument propose different explanations for the turning points of the growth cycle, so Marxists disagree on what factors cause the rate of profit to fall (see Wright, 1977 and Shaikh, 1978). In general, three competing explanations of the falling rate of profit are offered.

The first argument sees the movement of the rate of profit determined by the strength of labour. Thus, as workers find themselves in a relatively strong bargaining position and win wage increases in excess of productivity increases, so the rate of profit will fall (Wright, 1979). Weisskopf (1978) develops this "profit-squeeze" hypothesis in more detail. Boddy and Crotty (1975) explain the U.S. business cycle using the profit-squeeze argument and Glyn and Sutcliffe (1972) use it to explain the post-1960s decline of the British economy. Shaikh (1978) criticises these claims for failing to recognise that increases in the real wage do not necessarily imply a reduction in profitability. The profit-squeeze model can also be criticised for failing to specify the conditions under which labour is better able to secure wage increases.

The second Marxist explanation of the falling rate of profit is the over-accumulation thesis. The essence of this argument is that too much output is produced in the economy relative to the capacity of capital and labour to consume it. If markets do not clear then profits are reduced. Mandel (1975) and Baran and Sweezy (1968) are supporters of overproduction crises. Aglietta (1979) adopts a modified version of this argument, stressing the disproportionate growth of capital and consumer goods sectors, to explain in part the periodic contraction of capitalist economies. Bell (1977) and Weeks (1981) are critics of the over-accumulation argument. The central problem for the supporters of overproduction crises is to explain why capitalists will keep investing when their rate of profit is falling.

The third version of Marxist crisis theory argues that the replacement of labour by machinery in production decreases the very basis for profit, the exploitation of labour, and consequently the rate of profit falls. Mattick (1969), Yaffe (1973) and Shaikh (1978 and 1983) are supporters of this argument, while Hodgson (1974) dismisses it. The most damaging attack to the theory of the falling rate of profit was made by Okishio (1961). He proved that the adoption of viable technical changes must increase the rate of profit if markets clear and the real wage remains constant. van Parijs (1980) claims Okishio's theorem devastates Marx's theory of the falling rate of profit. Bowles (1981) concurs with Okishio, and Roemer (1978) too finds little support for the

Marxist position. Salvadori (1981), Shaikh (1983) and Hunt (1983) attempt to salvage the Marxist claim without success.

All three Marxist explanations for the falling rate of profit cannot stand alone as theories of economic crisis. In combination however, they offer a powerful explanatory tool with which to explain the dynamic of competition, technical change and the movement of the rate of profit. Together these arguments overcome most of the criticisms mentioned above. This "aggregate" Marxist model of economic crisis rests on the following logic.

Marx (1967) recognised that capitalists must compete to maintain their class position. They must continually advance capital in the search for profit. Capitalists compete largely through the adoption of different products and processes of production. The first firms to adopt more efficient techniques make super profits. These will be short-lived however as competitors imitate. Competition is not a static process for the general adoption of new products or techniques of production tends to lower commodity prices and therefore decreases profits for non-innovators. No firm in a competitive market can escape or ignore these pressures (Weeks, 1981). The continual search for profit ensures that there is no such thing as equilibrium in the capitalist economy.

From a position of relatively slow growth, assuming that the employment rate and real wages are relatively low, technical change increases the rate of profit fuelling faster accumulation. As the rate of growth of the economy increases sooner or later it will outstrip the rate of growth of the labour force. Further growth bids up the real wage as unemployment falls and labour finds itself in a stronger bargaining position. If wages rise, other factors being equal, the rate of profit will fall. This is the profit-squeeze argument.

To maintain profits capitalists must accumulate regardless of the rate of profit. If capitalists do not adopt new techniques of production they face lower profits through increased wages. They may however introduce technical changes in attempts to reduce costs. The relatively high price of labour induces firms to substitute capital for labour. For early innovators, such technical changes increase profits. For all innovators adopting more efficient techniques costs are reduced. However, the general adoption of labor-saving innovations tends to reduce the rate of profit. This is the falling rate of profit argument. The crisis will manifest itself in the form of the over-accumulation of capital and consumer goods.

This view of economic growth and recession is shared by Lipietz (1984) and Webber and Rigby (1986). Aglietta (1979) advances a still richer version of this thesis, linking the introduction of radically new technologies with new forms of labour control and wage bargaining. Bowles et al. (1983) advance a similar argument to explain the sustained post-war boom of the U.S. economy.

2.2.3 Summary

The viability of the Marxist explanation of crisis in capitalist economies hinges on two claims: that technical changes will exhibit a labour-saving bias when wages are relatively high; and most importantly, that labour-saving technical changes decrease the rate of profit. If the Marxist model can withstand Okishio's theorem then it offers a number of advantages over the long wave explanations of crises. Firstly, it explicitly defines the mechanisms that structure accumulation in capitalist economies, namely class struggle and competition. By recognising that capitalists cannot escape competitive pressures an important dynamic is captured by Marxist theory. Secondly, this dynamic explains why technical changes are introduced to the economy and it provides some indication of the characteristics of those changes. Thirdly, the Marxist model does not ascribe to a form of technological determinism that blindly views all technical changes as beneficial to the economy (see Rosenberg, 1976 and Gold, 1979 for example).

While the actions of capitalists are directed by movements of prices, Marx's accounting system is laid out in terms of labour values. Steedman (1977) argues that there is no direct relationship between values and prices and therefore that the Marxist model is inconsistent. Marshall (1987) supports this claim and therefore rejects Marx's theory of the falling rate of profit. Use of the Marxist model to explain the actions of economic agents demands that the relationship between commodity values and their respective prices be clarified.

2.3 Regional Growth and Crises

Section 2.2.2 outlined a model of economic crisis driven by the forces of class struggle and competition that define the capitalist mode of production. Though this abstract model argues that all capitalist economies will experience crises it does not assert that all industries and all regions will suffer the same crisis of profitability. While the specific sectoral and geographical extent of any particular recession is a matter for empirical investigation, a number of theoretical models purport to explain broader patterns of regional development. This section reviews several of these theories and argues that most are grounded upon models of regional competition that have little theoretical and empirical support.

2.3.1 The Neoclassical Model

The aggregate production function underlies the neoclassical regional growth model developed largely by Borts and Stein (1964) and Siebert (1969). In perhaps the simplest variant of the model aggregate output in a region is assumed to be a function of inputs of two homogeneous commodities, capital and labour. Borts and Stein (1964) argued that regional growth rate differences result from inequalities in the initial factor endowments of regions. However, assuming that factors of production are perfectly mobile and that economic agents have perfect information and respond rationally to market forces, the neoclassical model predicts that capital and labour will tend to migrate towards those regions where their respective marginal productivities are maximised. Thus it was hypothesised that capital will move from regions where the capital-labour ratio and wages were high, to regions where wages were low and returns to capital higher. In addition, labour might be expected to move from low to high wage areas. Over time then, competition will tend to remove factor price differences and equilibrate regional rates of growth.

Empirical tests of the neoclassical model using U.S regional data by Borts (1960) and later by Persky and Klein (1975) and Lande and Gordon

(1977) did not support the hypotheses that low wage regions would experience the fastest rates of capital formation and wage growth and that regional growth rates would thus tend to converge. Borts and Stein (1964) provide several explanations for the "perverse" results, noting that intra-regional flows of capital and labour to "more efficient" sectors of production might reverse the predictions of their model. In addition they hypothesised that regional variations in demand might encourage faster capital growth in regions where the capital-labour ratio was already high. Some of these claims were empirically corroborated.

The neoclassical equilibrium model does not seem particularly well-suited to explain uneven regional development. That model contains no mechanism for explaining marked variations in economic performance in general, let alone regional crises. Long-term differences in regional fortunes in the neoclassical model can only be explained by recourse to factors that prevent the attainment of equilibrium. Thus, uncertainty, economies of various types, spatial and other barriers to the mobility of factors of production and the existence of perfectly competitive markets might all sustain regional variations in economic performance. However, the existence of these "imperfections" casts doubt on the worth of the neoclassical model because in an "imperfect world" in the absence of equilibrium it is unclear what regional fortunes that model would predict (Richardson, 1973 and Clark et al., 1986).

More recently, the neoclassical model has come under even stronger criticism. Webber (1987a) has questioned the fundamental spatial logic of that model. He shows that the attainment of regional equilibrium may not require the equality of returns to capital over space and that under certain conditions, capital will flow between regions in equilibrium and not always towards that region where the rate of profit is greater. Persky and Klein (1975) have also demonstrated empirically that capital investment and profitability are not related in the manner suggested by strict neoclassical logic. While Jones (1975) has reviewed the criticisms surrounding the use of aggregate production functions, Barnes and Sheppard (1984) have also cast doubt on the efficacy of the neoclassical model by drawing out the spatial implications of reswitching arguments.

If a measure of the usefulness of a theory of regional development is to explain observed patterns, the neoclassical model must surely be rejected. The basic model predicts regional convergence. It does not comfortably account for regional divergence and the polarised growth and subsequent decay of regional economies and it offers few insights into the processes of long-run structural change.

2.3.2 Polarised Growth

In contrast to the neoclassical model, Myrdal (1957) predicted that the operation of the free market would lead to regional economic divergence as economies of scale favoured growth in a limited number of areas. He argued that the advantages of "backward regions" such as relatively cheap labour would be insufficient to prevent continued investment in growing regions. Myrdal's statements were formalised by Kaldor (1970). In tune with economic-base theory, Kaldor argued that regional fortunes would depend on the efficiency of their "export-sector". Efficiency for Kaldor depended on the rate of productivity growth. Productivity growth was itself hypothesised to be a function of technical change which in turn depended on output growth. This is the Verdoorn relationship.

While the model of polarised regional development appears to account for the limited spatial extent of manufacturing growth, it has two main failings. Firstly, it does not adequately explain why growth is concentrated in particular areas. Secondly, it cannot explain why prosperous regions experience decline.

Hirschman (1970) answered the first of these charges. He claims that the development of particular regions is a function of resource availability. This argument is not complete however, for it fails to recognise changes in the specific historical forms that the forces and relations of production may assume. Resource needs are dependent upon these forces, they do not arise in a social and economic vacuum.

The second criticism of the growth pole model again results from the static vision of the economy on which it is founded. Nevertheless, Casetti (1981) and Casetti and Jones (1987) try to explain the pattern of U.S. regional development, in particular the decline of the traditional manufacturing heartland, using the Verdoorn relationship. They argue that the migration of capital and labour from the snowbelt to the sunbelt reversed earlier productivity trends, favouring southern states after the early 1960s. These arguments must be treated cautiously. It is not clear whether the migration of resources prompted the productivity slowdown in the north-east, or whether industrial decline had begun earlier, productivity temporarily sustained as labour was laid off faster than capacity utilisation was reduced.

Richardson (1973) and Casetti (1981) have also attempted to explain "polarisation reversal". Richardson (1973) follows Myrdal (1957) in arguing that "spread effects" may diffuse investment to peripheral regions, but he provides no explanation for the timing of such trends or of the mechanisms that might promote them. Casetti (1981) argued that the decline of the traditional U.S. manufacturing belt followed declining returns to investment as the optimum scale of production was surpassed in that region, inducing firms to search for newer areas of profitable expansion. Gertler (1986b) soundly rebukes Casetti's claims on both theoretical and empirical grounds. The growth pole model is left without a viable explanation of regional competition and regional decline.

A somewhat different model of polarised growth was outlined by Perroux (1970). Though not a theory of regional development, Perroux's growth pole thesis, lent a spatial extension by Hansen (1970) and Hirschman (1970), reinforced the arguments of Myrdal. In searching for an explanation of long period structural change, after Kondratieff (1935) and Schumpeter (1939), Perroux claimed that growth manifests itself at different times and in different places, directed by the appearance of key industries and the "constellation of innovations spawned by them" (1970, p.94). Perroux provided a tenuous sketch of a cycle of growth, initiated by the development of a propulsive industry, characteristically large, fast growing and well integrated with the rest of the economy. Such an industry supposedly formed the nucleus of a growth pole sustained by innovation and scale economies much like those of the Verdoorn relationship. Perroux was also prescient in recognising the limits to growth, the "Achilles heel" of the growth pole thesis, though he did not provide an explanation of decline. Thomas (1975) makes the connection between the growth pole model of Perroux and the product-cycle model. The product-cycle model is examined in the following section.

The theory of polarised growth is a useful alternative to the neoclassical model of equilibrium, arguing that there are powerful agglomerative forces at work which tend to limit the spatial extent of growth. However, the precise forces generating polarised growth are neither well documented in fact nor well developed theoretically. The polarised growth thesis, abstracted from the changing social and economic relations that characterise real capitalist economies, cannot explain the varying pressures faced by capitalists over time and space. It is thus unable to explain how agglomeration itself may produce those very forces that make this spatial arrangement of productive capital inefficient. The recent reversals of regional fortunes in the U.S. and Britain cannot be explained by existing growth pole arguments.

2.3.3 The Product-Cycle Model

The product-cycle model developed originally by Vernon (1966) is currently receiving great attention in economic geography as an heuristic device that can supposedly unravel the complexities of the location of research and development activities, the growth of new, "especially high technology" firms and the emergent patterns of the new territorial division of labour. Following Taylor (1986), it is argued that this descriptive tool is unable to explain the changing geography of production.

In essence, the product-cycle model posits the existence of a life-cycle composed of distinct developmental stages through which all new commodities will pass. Stage one of this life-cycle is the innovation stage when a new product is introduced to the market. Output in this phase of the cycle is typically low, unit costs high and manufacture typically demands the application of skilled labour to refine product development. Stage two of the life-cycle is the growth or maturing stage, when demand increases, output and employment rise dramatically and cost economies begin to be sought in production. Stage three of the cycle is the standardisation phase, when output and employment is still high, but competition forces firms to actively seek cost reducing methods of production, typically through standardisation and scale economies. A fourth, or declining stage is sometimes added to this framework when competition erodes profits for all producers, in many cases eliminating employment.

The product-cycle model is lent a spatial dimension by the recognition that firms in different phases of the cycle have different requirements of their environment. Thus, in the innovation stage, access to skilled pools of labour, technical support and local sources of finance is crucial (see Oakey et al., 1982; Oakey, 1984; Haug, 1984 and Hall and Markusen, 1985). In the second and third stages of the cycle the search for cheap, low-skilled labour pushes firms to peripheral regions, sometimes overseas to developing nations. This is the thesis of the "new international division of labour" (Palloix, 1977). In this form, the product-cycle model may be regarded as a spatial extension of the hypothesis of long waves of innovation reviewed in Section 2.2.

Norton and Rees (1979) and Rees (1979) use the product-cycle model to explain the regional shifts of manufacturing employment in the U.S. in the last thirty years, arguing that regional growth is dependent on the attraction of firms in the expansive phases of the product cycle. In this sense, regional development is seen as a function of the ability of regions to attract firms in fast growing industries, after Fuchs (1962). Such arguments are very appealing, for a cycle of development is posited that appears to account for growth in different regions over time. However, the empirical evidence amassed by these researchers to support their claims is weak. Rees (1979) for example provides no evidence to link the history of the sunbelt with the evolution of any industry. Neither does he show that the sunbelt regions were the most advantageous production locations for any specific industrial sector during the 1960s and 1970s.

Markusen (1985) provides more empirical support for the product-cycle model. She argues that introducing a greater element of entrepreneurial choice and the possibility of oligopolistic market control through continual product refinement into the product cycle model (yielding her profit-cycle model), gives this approach some much needed flexibility (see the criticisms of Walker and Storper, 1981). A thorough and most informative examination of output and employment data over fifteen sectors of the U.S. economy is used to support her claims, though data on manufacturing profitability is conspicuous by its absence. In general, Markusen does not overcome the following deficiencies of the standard product-cycle model.

The first criticism of the product-cycle model is its blind faith in the benefits of innovation. The core of the model revolves around technological progress and its attendant investment needs, to the exclusion of market patterns and especially demand. All factors are subordinated to producing goods of increasing vintage and the product cycle is therefore guilty of technological determinism (Taylor, 1986).

The second problem with the product-cycle model is its rigidity, for it does not recognise the production demands of different commodities at different stages of their development and the peculiar locational needs that these may impose. Different goods necessitate different marketing strategies, some of which affect the choice of production sites. For example, some production of steel may be undertaken for defence reasons in unprofitable locations. Sensitive military items also may not be contracted out as freely as consumer commodities. Special production requirements too, notably the necessity to maintain very high quality standards have until recently prevented assembly of certain electronic components in Third World nations (Scott, 1986).

A third criticism is that the product-cycle model wrongly supposes that all commodities must follow the same production evolution from small scale labour intensive techniques through to standardised, mass production. Storper and Christopherson (1987) have argued that mass production is not necessarily the final stage in the process of product manufacture. The product-cycle model fails to recognise the different strategies firms can pursue in order to reduce production costs. They are not limited to seeking out cheap pools of marginalised labour, but may adopt alternative work practices such as just-in-time stock control and specialised sub-contracting (see Holmes, 1986), or the use of numerically controlled machine tools that can significantly reduce retooling costs and set-up time and greatly increase the flexibility of fixed capital. In addition, not all commodities pass through all the stages of the product-cycle. Commodities such as expensive automobiles for example may compete in specialised market niches and are continually produced with handicraft methods. Thus, the spatial evolution of different firms may be quite distinct.

In conclusion, the product-cycle model shares many of the shortcomings of behaviouralist views of firm location (see Watts, 1987). Built from the distillation of factors common to a heterogeneous assortment of firms in different positions (Massey, 1977), the product-cycle model is left bereft of analytical power (Scott and Storper, 1987). It does not explain the changing geography of production by simple recourse to a static model of development stages and the division of production tasks. The product-cycle model ignores the variety of responses to competitive pressures and the changing forms of the technological and social constraints on production that give rise to completely new geographies of production.

2.3.4 Radical Theories of Uneven Development

Harvey (1982, p.374) correctly points out that the key issue in explaining uneven development is to search for theory that is based on the basic processes that structure the economy, yet which is robust enough to handle the myriad forms in which those processes may reveal themselves over the land. Massey (1978), for one, has sought to situate uneven geographical development in the central dynamic of the capitalist mode of production, arguing that:

> The process of accumulation within capitalism continually engenders the desertion of some areas, and the creation of new reserves of labour-power, the opening up of other areas to new branches of production, and the restructuring of the territorial division of labour and class relations overall. (1978, p.107).

Harvey (1975) and Walker (1978) go further, claiming that a central mandate of capital is the "annihilation of space by time". Thus, through increased mobility capital hopes to realise, "...a kind of geographic optimisation of investment opportunity", a reserve of places for accumulation, or a, "lumpengeography of capital" (Walker, 1978, p.32). While Massey (1978 and 1984), Walker (1978), Harvey (1975 and 1982) and others (see Browett, 1984), all view space as another facet of the investment decision and one which like the choice of technique can be used in the competitive struggle for profits, Mandel (1975), Carney (1980) and Soja (1980) maintain that uneven regional development is necessary for the perpetuation of the capitalist mode of production. Clark (1980) and Browett (1984) are correct in dismissing such claims. While uneven development may aid the accumulation of capital by providing reserves of labour and markets in under-developed regions, it is in no sense a requirement for continued accumulation. Though such debates might appear at first blush to be somewhat ephemeral, they point to important developments in Marxist studies that attempt to uncover the relationships between social structure and spatial form.

Within the Marxist fold, there are two distinct methods of examining regional uneven development at the sub-national level. The first of these borrows concepts developed at other spatial scales, notably those of dependency theory and unequal exchange which are usually applied at the international level. The second approach has been to analyse the process of capital accumulation and build a "regionalisation of space" upon the particular characteristics that process exhibits at particular times. Jensen-Butler (1982) provides a comprehensive review of these approaches which are now examined briefly.

2.3.4.1 Dependency Theory and Unequal Exchange

Dependency theory draws upon the notions of imperialism to provide a radical model of uneven development over space. It suggests that relations of domination and subordination exist between regions in much the same way as the class relations that are definitive of capitalist economies. Frank (1969) provides perhaps the best known version of this theory. He argues that the plight of backward nations is nothing to do with their lack of resources, but is the product of their dependency on more developed nations. The mechanism of unequal exchange is usually posited as the process by which relations of economic domination are perpetuated, with hinterland regions characterised by pre-capitalist modes of production exchanging commodities at cost with profit being appropriated by the capitalist firms of the metropolitan centres.

While Frank argued that capital tends to homogenise nation spaces and prevent the emergence therein of regions based on different modes of production, Laclau (1971) argued that pre-capitalist modes may persist alongside capitalist ones (see Matthews, 1980). This idea is developed by Carney and Hudson (1978) to explain the slow pace of development of the north-east of England, by Lipietz (1980) to characterise patterns of accumulation in France and by Matthews (1980) to explain the emergence of a distinct Canadian regionalism.

Dependency theory appears to offer the advantage of explaining regional development using concepts drawn immediately from a broader theory of society, thereby sidestepping the problems of inductive theorising, in particular, the identification of contingent categories and relations as necessary ones (see Bhaskar, 1975 and Sayer, 1979). Dependency theory has certain shortcomings however. In particular it is guilty of transposing social relations into spatial ones. This has two immediate drawbacks. Firstly, certain regions are seen as dominating others. This is a form of the spatial fetishisation that Soja (1980) rightly objected to, for individuals or classes of individuals dominate others, not regions. This reification of social relations has important consequences, for it is a short (policy) step from the claim that a region is performing poorly, to a solution which is inevitably aimed at one or a number of the characteristics of the region in question (Massey, 1978). Secondly, the position of social classes does not change within a mode of production and dependency theory resting upon an analogous division of territory, suffers from the same problem as orthodox polarisation models in that it posits an immutable core-periphery structure (Webber, 1982a). Dependency theory is thus unable to explain reversals of regional fortunes (though Matthews (1980) attempts to explain the decline of a once prosperous maritime Canada using this concept). Dependency theory also fails to explain the uneven growth of industrialised regions that are fully integrated with the capitalist mode of production.

Unequal exchange may be regarded as the economic mechanism by which core regions of a country (or the world in the case of dependency theory) maintain their dominance over peripheral areas. Unequal exchange results from the deviation of commodity prices from their respective values as a result of competition and the enforcement of a uniform rate of profit. Foot and Webber (1983), in criticising the work of Emmanuel (1972), provide a thorough review of the theory of unequal exchange noting that it may result from either variations in the value composition of capital or the rate of exploitation between firms in the different sectors of production. The transfer of value through unequal exchange is given spatial form by assuming that regions specialise in the production of particular commodities. Again developed for use principally in the sphere of international development, the concept of unequal exchange has been used to explain uneven regional growth at the sub-national level (see Lipietz, 1980).

Unequal exchange is not a theory of regional development. It is simply one form of competition between capitalists, namely that between firms in different sectors of the economy. In the Marxist model it thus takes the place of short-run adjustments to variations in factor prices that generate capital and labour flows in the neoclassical model. In so far as both mechanisms rely on a tendency for the rate of profit to equalise their operation is amenable to theoretical and empirical scrutiny. Both mechanisms may be guilty too of ignoring another vital aspect of competition, that between firms in the same sector. This form of competition does not require that rates of profit between competing firms converge, merely that competition enforces a uniform selling price in the market. As in the case of unequal exchange, the veracity of this form of competition depends on the diversity of techniques employed in the economy. This diversity is likely to depend in part on the spatial extent of markets.

2.3.4.2 Regimes of Accumulation

The second of the "Marxist explanations" views regional development as the spatial manifestation of the process of capital accumulation (Carney, 1980 and Lapple and van Hoogstraten, 1980). This approach does not impose an arbitrary empirical classification upon the landscape, but rather argues that regions must be constituted as an effect of the analysis (Massey, 1978). Thus, regions are defined at a particular moment in time on the basis of similarities in the development of the forces and relations of production and thus of the opportunities different places present for the accumulation of capital. This "regionalisation" is historically specific, for the processes of accumulation continually reorder, or restructure, this landscape of opportunity for capital (Massey, 1978, 1984; Walker, 1978; Harvey, 1982; Webber, 1982a and Bradbury, 1985).

The abstract cyclical model of capitalist accumulation outlined in Section 2.2.2 provides the basis for various Marxist interpretations of regional development. While this structure does not determine the actions of individual economic agents and thus the changing geography of production, it does constrain these actions. Explaining concrete patterns of regional development thus demands empirical analysis of how class struggle and capitalist competition manifest themselves at particular times and in particular places and how capitalists and labourers respond to these forces, producing new or reinforcing old social and economic geographies.

While the causal mechanisms that structure the capitalist mode of production do not change, they may assume a variety of forms, constrained by existing technical knowledge, by the distribution of resources, both natural and socially created, and by social relations between capitalists and labourers. Although, new technologies and new forms of capital-labour relations are not seen to emerge in the regular fashion predicted by the long-wave or product-cycle arguments, a number of distinct periods within the capitalist mode of production have been identified. The bases for these "sub-modes" remain disputed however. Thus, Gibson and Horvath (1983) identify a number of sub-modes within the history of capitalist production, defined by distinct market structures and relations of competition. Mandel (1975) too, recognises a series of rounds of accumulation in capitalist economies. For him though, each is dependent on the introduction of new forms of machine-power, associated technologies and social relations of production. Peet (1983) also emphasises the importance of social relations in structuring the temporal and spatial dynamics of accumulation. He thus posits the existence of "class struggle cycles", arguing that the geography of production changes through time as labour in particular regions gains power relative to capital and promotes region-specific crises that drive capital to sites of unorganised and cheaper labour. Aglietta (1979) has advanced perhaps the most persuasive interpretation of cycles of growth and recession, identifying three "regimes of accumulation" since the mid-eighteenth century, each predicated on the introduction of new products and processes of production, on new forms of labour control and wage bargaining, in short on the restructuring of the spheres of production and consumption.

The spatial dimension of these arguments are amplified by Massey (1978 and 1984), Dunford et al. (1981), Webber (1982a), Lipietz (1982a) and Marshall (1987). Webber (1982a) argues that the logic of each new round of accumulation demands much new investment. Establishing this logic may be beyond the financial capabilities of individual capitals and so investment is shared through agglomeration giving each phase of accumulation a distinct geography. Dunford et al. (1981) show that these geographies of production vary between regimes as technology frees capital from previous locational constraints, as the emergence of new sectors of production places new demands on the existing distributions of resources, as the distribution of capital and labour in space is reshaped by new investment and as different threats to continued accumulation demand different responses on behalf of capital. Lipietz (1982a) uses the logic of regimes of accumulation to explain the increasing global integration of commodity production, while Dunford et al. (1981) and Marshall (1987) uses these same arguments to explain long waves of industrial and regional development in Britain.

Just as a new phase of growth is constitutive of a new regionalisation, so too economic crises exert a differential impact over space. Massey (1981) for example, examines how different forms of competition in the electrical engineering and electronics industries of the U.K. produced different responses on behalf of the affected capitals. Massey and Meegan (1982) extend this analysis, identifying three forms of restructuring in British industry and the effects of each on output, productivity and thus employment. Bluestone and Harrison (1982) also note the locational impacts of different forms of industrial restructuring in the U.S. frostbelt. Holmes (1983 and 1986) and Malecki (1986) examine a variety of different competitive strategies of firms while Sayer (1985 and 1986) dispels monolithic theoretical concepts such as the "new international division of labour" and calls for more careful empirical analysis of the spatial behaviour of individual industries.

Thus, periods of growth and recession are seen to restructure space as they redistribute capital and labour between firms and industries, insodoing reshaping the relative positions of capitalists and workers and the sectoral and spatial intensity of competition and class struggle. The geography of production at a given time can therefore be conceived as the result of a series of previous rounds of investment in space each expressing the historical stage of development of the forces and relations of production (Massey, 1978). This geography will vary through time and it will be similar in some sectors of production and dissimilar in others. It does not conform to a prescribed pattern.

2.3.5 Summary

The Marxist model of uneven regional development has several advantages over the other theories examined in this section. Firstly, it is superior to the neoclassical model for it incorporates an explanation of uneven development that is quite easily lent a spatial dimension. Secondly, it does not posit an immutable geography of production like the polarised growth or dependency theories, recognising that new technologies and new forms of social relations of production free firms from previous spatial constraints. Thirdly, unlike the product-cycle model, it does not assume that industries follow common paths of development with similar locational demands over time. Rather, the Marxist model argues that new processes and products of production are "born" of structural changes in the economy; of attempts by capitalists to remove existing barriers to more profitable accumulation. Success for firms can only be limited however, for competition ensures that super-profits will be eroded and the contradictions inherent in the capitalist mode of production will once again threaten continued accumulation, necessitating further innovation and in so doing reworking the geography of production.

2.4 Empirical Work in Marxist Crisis Theory

There have been a number of attempts to link Marxist theory with concrete patterns of industrial and regional uneven development. Massey (1981) for instance examines the development of crisis in particular industries, Mahon (1984) and Holmes (1983) study the reorganisation of selective industries in the face of crises and Scott (1986) and Sayer (1986) document the development of emerging industries. Similarly, Bluestone and Harrison (1982), Bradbury and St. Martin (1983), Jensen-Butler (1982) and Webber (1986) examine the effects of economic recession on particular regions and Massey and Meegan (1982), Hudson (1983) and Foot (1987) draw out the links between uneven economic development and spatial restructuring.

A common criticism of this work is that while it links the concrete patterns of economic change with the more abstract arguments of

Marxist theory, it provides little direct empirical support for that theory. Thus, although regional variations in rates of unemployment, firm closures and capital investment may be symptomatic of uneven development and economic crises, they may be explained by a number of theoretical arguments. For example, the growth pole and product-cycle models explain uneven regional development on the basis of spatial variation in rates of technical change and the distribution of industries and they explain the onset of a recession by a general slowdown in the pace of innovation. While not claiming that empirical analysis can conclusively arbiter between the competing explanations of crises and uneven development, the Marxist line is rarely bolstered by empirical investigation.

There are at least two reasons for the dearth of empirical Marxist work. Firstly, it is argued that Marxist categories are abstract and therefore unquantifiable (see Althusser and Balibar, 1970 and Wright, 1979). Secondly, Marxist theory rests on the labour theory of value and value categories cannot easily be estimated from price data. This argument is supported by Sharpe (1982) among others.

The first of these claims is based upon a false interpretation of the meaning of abstraction (see Bhaskar, 1975 and 1979). Marxist categories are amenable to measurement if they can be defined precisely enough. Indeed, Roemer (1981) argues that one of the most important tasks of empirical investigation is to sharpen the definition of theoretical categories so that they may be measured. The second claim too may be rejected if one is willing to abandon the transformation problem as traditionally defined.

The Marxist theory of crisis rests upon the movement of the rate of profit. Empirical examination of Marxist crisis theory demands that the rate of profit be defined precisely enough to examine the various pressures that act upon that rate. These are identified by Marx (1967). Until recently, measures of the rate of profit were not up to this task (see Rigby, 1983). The most notable attempts to measure the rate of profit are those of Gillman (1957), Sharpe (1982), Weisskopf (1982) and Shaikh (1983). All of these measures fail to define the rate of profit correctly however for they all measure the rate of profit as the ratio of profit to the costs of production, rather than the capital advanced. Webber and Rigby (1986) show the significance of this omission.

Webber and Rigby (1986) and Webber (1987b) overcome previous errors in estimating Marxian categories. Webber and Rigby (1986) outline a novel way of measuring the value rate of profit and its component variables. They use this measure to examine the post-war history of the Canadian economy and are able to provide clear support for the "abstract" Marxist arguments of the falling rate of profit. Webber (1987b) has extended this work. He discusses some of the problems of measuring Marxist categories in general and offers a thorough explanation of the relationship between labour values and expected prices after Farjoun and Machover (1983).

While more recent work by Webber and Tonkin (1987) extends the investigation to individual industries there is as yet no detailed examination of the Marxist model at the regional level. Thus, while the theory of the falling rate of profit can be shown to provide a viable explanation of capitalist crisis, it is unclear whether or not economic recessions affect all regions to the same extent and whether they affect them in similar ways.

2.5 Conclusion

This chapter reviewed a number of competing explanations of economic crisis. Explanations that separate the cause(s) of economic recession from forces endogenous to capitalist economies are rejected for they fail to recognise the cyclical character of growth in capitalist economies. The Marxist theory of the falling rate of profit provides perhaps the clearest explanation of crises. This theory has recently been criticised by Okishio (1961) and its logical consistency is in question.

Economic growth and decline exert an uneven impact over space. Thus, it was argued that at any time growth is focused in one or a few regions most suited for the accumulation of capital, given the existing state of the forces and relations of production. The influence of growth and more especially economic decline at the regional level is by no means clear. In part this reflects two problems. The first is the lack of an adequate model of the processes of regional competition and the second results from the lack of detailed empirical work at the regional level.

The aim of this thesis is to understand the factors influencing regional uneven development. To achieve this aim, a model is required that explains why capitalist economies do not enjoy continued uninterrupted growth and how regions compete for available profits. Marxist theory offers the most suitable framework for the analysis of these issues. Use of this theory demands that the explanation of economic crisis be clarified in light of Okishio's (1961) claims. Two arguments are especially critical to the Marxist model. Firstly, do labour-saving technical changes decrease the rate of profit, and secondly, why should technical change exhibit a labour-saving bias? These issues are examined in Chapters 5 and 6. Extension of the Marxist model to examine regional uneven development demands a thorough investigation of the effects of technical changes on measures of regional economic performance. This is the subject of Chapter 7. To link the theoretical analysis with the empirical investigation an accounting framework is required that provides a consistent link between commodity values and prices. This is the task of the next chapter.

CHAPTER 3

VALUE AND PRICE

3.1 Introduction

The relationship between labour values and prices of production, or equilibrium prices, has occupied a central position in the development of Marxist economic theory. Debate of this issue began shortly after the publication of Volume 3 of Capital with Bohm-Bawerk's assertion of the inconsistencies between Volume 1 and Volume 3. Bortkiewicz (see Sweezy, 1970) was quick to examine the arguments, outlining a number of solutions to the apparent problem. Sweezy (1970) provides an introductory review of this early debate, while Desai (1979) lays bare the finer details of this and much of the subsequent discussion. Recently, Steedman (1977) has rejected the claim that labour values regulate prices of production. He goes on to deny the relevance of Marxist economic theory in toto, claiming that prices of production can be calculated from physical input-output data alone and thus abrogating the utility of the labour theory of value. Steedman's comments drew quick response with the publication of further solutions to the so-called transformation problem, notably those by Shaikh (1977), Morishima and Catephores (1978) and Lipietz (1982b). Morishima (1973) may have anticipated Steedman's concern, presenting arguments in defence of the efficacy of the labour theory of value regardless of the value-price issue. Sraffa (1960), also contributed to the value-price debate by presenting a critique of economic theory that questioned the basis of the aggregate production function and neoclassical capital theory in general. No longer could one appeal to the prevailing technology of an economy for an explanation of the distribution of the surplus product. Such an explanation must be sought in an analysis of the social as well as the technical conditions of production. The labour theory of value explains the distribution of value added on precisely these grounds.

This chapter provides a brief review of the relationship between commodity values and prices. A Marxist accounting framework, which incorporates both values and prices, will inform much of the subsequent discussion throughout the thesis. The chapter is organised in the following way. In Section 2, an accounting scheme based on the labour theory of value is presented. Some misconceptions about the generality of the conditions under which commodity values can be calculated are cleared up. In Section 3, equilibrium prices are defined. The formation of equilibrium prices, or prices of production, assumes that competition enforces a uniform rate of profit in the economy. Given this assumption, the derivation of prices of production from labour values is supposedly possible. The assumption of a uniform rate of profit has recently been attacked by Farjoun and Machover (1983) who contend that forces of competition are just as likely to cause the rate of profit to diverge between sectors of the economy as they are to cause it to equalise. The claims of Farjoun and Machover make redundant the question of the relationship between values and prices, but not for the reasons suggested by Steedman (1977). These arguments are discussed in Section 4. Section 5 establishes the relations between values and expected prices after

Farjoun and Machover (1983). In Section 6, two forms of capitalist competition are identified. The central arguments of the chapter are summarised in the seventh and concluding section.

3.2 A Marxist Accounting System

Let an economy produce n commodities the first m of which are capital goods. Capital goods are used as inputs in the production of all commodities. The remaining n-m goods produced in the economy are consumption commodities. These goods are purchased by labour with wages and by capitalists out of profits. The capital goods as inputs to production can be further distinguished by their useful service life. Some capital goods may be used in production for several turnover periods. These inputs are commonly termed fixed capital. Assume that there are k (<m) such capital goods. The remaining capital goods have a service life of only one round of production. These commodities are termed circulating constant capital inputs and must be renewed at the start of each period of production.

The techniques of production in the economy are represented by a matrix of inter-commodity or inter-industry input-output coefficients, denoted by $\mathbf{A}$, and by a row vector of labour input coefficients, denoted by $\mathbf{l}$:

$$\mathbf{A} = \begin{matrix} a_{11} & a_{12} & \cdots & a_{1j} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2j} & \cdots & a_{2n} \\ \cdot & \cdot & \cdots & \cdot & \cdots & \cdot \\ \cdot & \cdot & \cdots & \cdot & \cdots & \cdot \\ a_{i1} & a_{i2} & \cdots & a_{ij} & \cdots & a_{in} \\ \cdot & \cdot & \cdots & \cdot & \cdots & \cdot \\ \cdot & \cdot & \cdots & \cdot & \cdots & \cdot \\ \cdot & \cdot & \cdots & \cdot & \cdots & \cdot \\ a_{n1} & a_{n2} & \cdots & a_{nj} & \cdots & a_{nn} \end{matrix}$$

$$\mathbf{l} = l_1 \quad l_2 \quad \cdots \quad l_j \quad \cdots \quad l_n$$

where $a_{ij} \geq 0$, $l_j > 0$, for $i,j = 1,\ldots,n$.

The elements a_{ij} of matrix **A** denote the physical amount of commodity i required on average to produce one unit of commodity j. The elements l_j of vector **l** denote the direct labour time required on average to produce one unit of commodity j. The capital and labour input coefficients are averages across all firms engaged in the production of a given commodity type. Each commodity is assumed to be produced by a large number of firms which collectively comprise an industry. Individual firms in any industry maybe more or less efficient than average for that sector and will thus have capital and labour input coefficients that are greater or less than the economy-wide averages.

3.2.1 The Labour Value of Commodities

The labour value of a commodity is measured as the abstract labour time (direct and indirect) socially necessary for its production. Using the technical coefficients of production, the labour values of all commodities produced in the economy are defined after Morishima (1973) as

$$\boldsymbol{\lambda} = \boldsymbol{\lambda}\mathbf{A} + \mathbf{l} \qquad (3.1)$$

$$= (\mathbf{I}-\mathbf{A})^{-1}\,\mathbf{l} :$$

where $\boldsymbol{\lambda}$ is a 1xn row vector of commodity values:

$\mathbf{I}$ is an nxn identity matrix.

Equation 3.1 has a solution as long as the inverse of the matrix ($\mathbf{I}-\mathbf{A}$) exists. It is assumed that the matrix $\mathbf{A}$ is indecomposable and productive, thus assuring that commodity values are positive.

Morishima (1973) argued that equation 1 provides an accurate measure of commodity values only if the following assumptions hold:

1. All commodities have the same period of production:
2. Production processes are point-input point-output:
3. There is no choice of technique:
4. There is no joint production:
5. There is no fixed capital:
6. Labour is the only value-creating factor of production.

Most of these assumptions are deforming, they bear no relationship to production conditions within the capitalist economic system. The usefulness of equation 3.1 is thereby questioned. Webber and Rigby (1986) and Webber (1987a), in developing a more general set of equations to measure commodity values, have shown that Morishima's system is not restricted by all the assumptions noted above.

In short, assumptions 1 and 2 do not affect commodity values. However, they do influence performance measures of the economy such as the rate of profit. Distinguishing between the costs of production and the capital advanced for production (see later) allows one to take full account of turnover times and the time interval over which inputs are consumed. Assumptions 1 and 2 can therefore be relaxed. Assumption 3 fails to appreciate Marx's very definition of commodity values. The term "socially necessary" in fact assumes commodities are produced by a variety of techniques, defining a commodity's value as a weighted average of the labour times embodied in these techniques. Assumption 3 is thus wrong and can be dropped. Assumption 4, in general, may also be relaxed. Joint production is said to occur when a firm produces more than one type of commodity. A method of calculating commodity values with joint production is given in Webber (1987b). Assumption 5 is relaxed in the following material. Given a pattern of depreciation, and assuming the life of fixed capital is known (the number of turnover periods over which it retains part of its value), it is possible to calculate the value of fixed capital inputs to production. Assumption 6 is required in the following arguments. A more general measure of the labour value of commodites is now presented based on Webber and Rigby (1986) and Webber (1987b).

3.2.2 A Reformulation of Commodity Values

For each unit of work performed by labour a given amount of value is created. The unit of work is assumed to be the labour day and the amount of value created on average by one worker during the day is assumed to be equal to unity. For this day's labour, a worker receives a wage. This wage may vary between the firms in an economy. It is assumed in the following analysis that the real wage is constant within an industry or department of production. In physical terms, the (real) wage comprises of a basket of consumer goods. The value of the wage in department j is

$\boldsymbol{\lambda} \mathbf{d}_j = \lambda_{Lj}$:

where $\mathbf{d}_j$ is the real wage in department j, an nx1 column vector of

commodities. (The first m elements of $\mathbf{d}$ will be zero.):

λ_{Lj} denotes the value of a unit of labour-power in department j.

A defining assumption of the capitalist mode of production is that the length of the working day is greater than the time required by labour to reproduce the equivalent of its own value. If the unit of work is assumed to be the day, and the value of a day's labour in any department j is assumed to be equal to unity, then each labour-day worked a surplus accrues to the owners of the means of production in department j. This surplus is $1-\lambda_{Lj}$.

The direct labour input in production is l_j units of abstract or socially necessary labour per unit of output of department j. A quantitative representation of the term "socially necessary" is provided by Webber (1987). The socially necessary labour time required for the production of a commodity j is measured as the weighted average of the labour time, direct and indirect, required by all firms engaged in the production of commodity j. If the value of labour-power in department j is λ_{Lj}, then the variable, or direct labour, cost of production per unit of output of department j is $\lambda_{Lj} l_j$. The variable capital that has to be advanced to meet those labour costs is different however. In addition to the labour costs, the variable capital advanced also depends upon the number of turnovers per year in department j (t_j) and the extent to which capitalists can spread labour costs over the period of production in department j (α_j).

To appreciate the distinction between the costs of production for a given period of time, say one year, and the capital that has to be advanced to meet those costs, consider an industry that has a period of production equal to Z days. This industry has t (=365/Z) production or turnover periods per year. A firm in this industry initiates production at the start of the year with capital C. After Z days the firm holds capital equivalent to C+ΔC. If no accumulation occurs within the year and if Z<365 then the original capital can be reinvested and a further surplus ΔC realised. The capital advanced to meet the costs of production can be further reduced by spreading input payments over the turnover period. For example, assume that the cost of labour for a ten week production run is $100 per week for a total cost of $1000. If this wage bill is paid at the start of the production period then the capital tied up amounts to 10,000 dollar-weeks. If labour is paid at the end of each week's work however, the total capital advanced is only

$100 x 9 weeks

$100 x 8 weeks

$100 x 7 weeks

.   .

.   .

$100 x 1 week

for a total capital outlay of 4,500 dollar-weeks.

In one year therefore, letting α = 4,500/10,000:

C = capital advanced for production:

tC/α = total costs of production:

$t\Delta C$ = total surplus realised.

Thus, the capital advanced for production over a given period maybe significantly lower than the costs of production for the same period. For a unit of output in department j therefore:

Variable capital costs = $\lambda_{Lj} l_j$:

Variable capital advanced = $\alpha_j \lambda_{Lj} l_j / t_j$:

where $0 < \alpha_j \leq 1$, for all j.

Constant capital, or indirect labour, costs of production include two quite different types of expenditure. Firstly, there are costs for raw materials, fuel and electricity. These are circulating constant capital costs. Denote these inputs as a_{ij} units per unit of output of department j, where i is restricted to the range k+1,k+2,...,m. The circulating constant capital costs of production per unit of output of commodity j are $\sum_{i=k+1}^{m} \lambda_i a_{ij}$. Following the arguments above, for a unit of output of commodity j:

Circulating constant capital costs = $\sum_{i=k+1}^{m} \lambda_i a_{ij}$:

Circulating constant capital advanced = $\sum_{i=k+1}^{m} \beta_j \lambda_i a_{ij} / t_j$:

where $0 < \beta_j \leq 1$, for all j.

β represents the delay of payment of circulating capital inputs. The second type of constant capital expenditure is depreciation, the quantity of value given up by fixed capital to output. Let c_{ij} be the amount of gross fixed capital required per unit of output of department j. In this case i is restricted to the range i=1,..,k. Each unit of fixed capital i has a life of T_i years. Thus, the value of gross fixed capital required per unit of output of department j is $\sum_{i=1}^{k} \lambda_i c_{ij}$. Depreciation in department j is $\sum_{i=1}^{k} \frac{\lambda_i c_{ij}}{T_i}$. This valuation assumes that output is constant each production period and that fixed capital is valued on a current rather than an historic basis. If the gross fixed capital has been in place for some years, then several contributions have been made by the fixed capital to output (through "wear and tear"). Thus, the net fixed capital stock remaining is only $\sum_{i=1}^{k} \upsilon_i \lambda_i c_{ij}$. υ_i, for i=1,...,k, represents the proportion of value of fixed capital commodity i put in place in some year t and still remaining.

Combining the information above, the value of a commodity j, for j=1,...,n, is

$$\lambda_j = \sum_{i=1}^{k} \frac{\lambda_i c_{ij}}{T_i} + \sum_{i=k+1}^{m} \lambda_i a_{ij} + l_j$$

$$= \boldsymbol{\lambda}\mathbf{a}_j + l_j, \qquad (3.2)$$

where $\frac{c_{ij}}{T_i} = a_{ij}$, for $i=1,\ldots,k$.

3.2.3 Measures of Performance

If the amount of each commodity produced in the economy in a given period of time, say one year, is known, then several variables that measure the performance of individual industries and the economy as a whole can be calculated. To see this, let the output of an industry j in a given production period be x_j. Then the total amount of labour used in industry j during this period is $l_j x_j$, and the total surplus produced in industry j during the year is

$$S_j = (1-\lambda_{Lj}) l_j x_j. \qquad (3.3)$$

The value of the constant capital advanced in production in industry j, both fixed and circulating, is

$$C_j = \sum_{i=1}^{k} \upsilon_i \lambda_i a_{ij} + \sum_{i=k+1}^{m} \beta_j \lambda_i a_{ij}/t_j \qquad (3.4)$$

$$= \boldsymbol{\lambda}\mathbf{k}_j:$$

where $\mathbf{k}_j$ is an nx1 element column vector of the fixed and circulating constant capital advanced per year in industry j.

The variable capital advanced per year in industry j is

$$V_j = \alpha_j \boldsymbol{\lambda} \mathbf{d}_j l_j x_j / t_j \ . \tag{3.5}$$

Using these terms, the value composition of capital in industry j is defined as

$$q_j = \frac{C_j}{V_j} = \frac{\boldsymbol{\lambda} \mathbf{k}_j x_j}{\alpha_j \boldsymbol{\lambda} \mathbf{d}_j l_j x_j / t_j} \ . \tag{3.6}$$

The value rate of exploitation in industry j is

$$e_j = \frac{S_j}{V_j t_j / \alpha_j} = \frac{(1-\boldsymbol{\lambda} \mathbf{d}_j) l_j x_j}{\boldsymbol{\lambda} \mathbf{d}_j l_j x_j} \ ; \tag{3.7}$$

and the rate of surplus value in industry j is

$$e_j t_j / \alpha_j = \frac{S_j}{V_j} = \frac{(1-\boldsymbol{\lambda} \mathbf{d}_j) l_j x_j}{\alpha_j \boldsymbol{\lambda} \mathbf{d}_j l_j x_j / t_j} \ . \tag{3.8}$$

Combining equations 3.3 through 3.8, the annual value rate of profit in industry j is

$$\pi_{vj} = \frac{S_j}{C_j + V_j} = \frac{(1-\boldsymbol{\lambda} \mathbf{d}_j) l_j x_j}{\boldsymbol{\lambda} \mathbf{k}_j x_j + \alpha_j \boldsymbol{\lambda} \mathbf{d}_j l_j x_j / t_j} \ ; \tag{3.9}$$

$$= \frac{e}{[q_j + 1]\alpha_j / t_j} = \frac{(1-\boldsymbol{\lambda} \mathbf{d}_j) l_j x_j / \boldsymbol{\lambda} \mathbf{d}_j l_j x_j}{[\boldsymbol{\lambda} \mathbf{k}_j x_j / \alpha_j \boldsymbol{\lambda} \mathbf{d}_j l_j x_j / t_j + 1]\alpha_j / t_j} \ .$$

The value rate of profit may vary between sectors because individual industries employ different quantities and combinations of inputs of capital goods and labour. Thus, the rate of exploitation, the value composition of capital and the annual number of turnovers will not be the same in all industries. Those firms and industries with relatively high rates of exploitation, relatively low value compositions of capital, or a relatively high number of annual turnovers, will enjoy above average value rates of profit.

For the economy as a whole a set of performance measures equivalent to those above can be defined. These measures are simply weighted averages of the industry measures with sectoral output levels as weights:

$$q = \frac{C}{V} = \frac{\sum_j \boldsymbol{\lambda k}_j x_j}{\sum_j \alpha_j \boldsymbol{\lambda d}_j l_j x_j / t_j} \; : \tag{3.10}$$

$$e = \frac{S}{V\alpha_j/t_j} = \frac{\sum_j (1-\boldsymbol{\lambda d}_j) l_j x_j}{\sum_j \boldsymbol{\lambda d}_j l_j x_j} \; : \tag{3.11}$$

$$\pi_V = \frac{S}{C+V} = \frac{\sum_j (1-\boldsymbol{\lambda d}_j) l_j x_j}{\sum_j \boldsymbol{\lambda k}_j x_j + \sum_j \alpha_j \boldsymbol{\lambda d}_j l_j x_j / t_j} \; : \tag{3.12}$$

$$= \frac{e}{[q + 1]\alpha_j/t_j} = \frac{\sum_j (1-\boldsymbol{\lambda d}_j) l_j x_j / \boldsymbol{\lambda d}_j l_j x_j}{\sum_j [\boldsymbol{\lambda k}_j x_j / \alpha_j \boldsymbol{\lambda d}_j l_j x_j / t_j + 1]\alpha_j / t_j} \, .$$

3.3 Equilibrium Prices

Consider a capitalist economy operating with the technology defined in the Section 3.2. Firms advance capital to meet costs of production, including wages, before production commences. Assume that competition between workers for available employment equalises the wage rate per unit of labour in all departments. In addition, assume that capitalists can invest in any department in search of the greatest profit. In "equilibrium" then, all capital makes the same rate of profit.

Given these assumptions, the unit prices of the n commodities in the economy are given by

$$\mathbf{p} = (1+\pi_p)(\mathbf{pA} + \mathbf{pdl}). \tag{3.13}$$

Letting $\mathbf{M}$ = the matrix of technical coefficients augmented by the real wage

$$\mathbf{p} = (1+\pi_p)\mathbf{pM}\text{ , or}$$

$$\frac{1}{(1+\pi_p)}\mathbf{p} = \mathbf{pM}\text{ .}$$

The set of equations 3.13 contains n+2 unknowns, the prices of the n commodities, the real wage and the equilibrium rate of profit. By convention, the real wage is given along with the technical coefficients of production. Then, by specifying the price of one commodity, the numeraire, the system of relative prices is uniquely determined (up to a scalar) along with the equilibrium rate of profit. These prices depend on the techniques of production and the assumed distribution of the surplus between wages and profits. These prices are independent of the scale and composition of output (see Harris, 1978).

3.4 The Assumption of a Uniform Rate of Profit

Economists of most theoretical persuasions agree that market prices, or the prices actually paid for commodities, fluctuate in a random manner over time as conditions of demand and supply change. These prices cannot therefore be accurately determined. It is also commonly supposed that the interplay of supply and demand is itself regulated by the "law of equal profitability" (Shaikh, 1977). That is, competition is assumed to drive capital from sectors with a relatively low rate of profit into those sectors with relatively high rates of profit. The movement of prices as supply and demand adjust to the flows of capital is supposed to push the economy towards an equilibrium characterised by an equal rate of profit on capital invested in all branches of production. In such an equilibrium supply and demand variations are assumed away and thus market prices are stable. It is claimed (Steedman, 1977) that these equilibrium (market) prices can be determined by the method presented above.

Most Marxists contend that equilibrium prices and the rate of profit can only be explained through the adoption of the labour theory of value (see Mandel and Freeman, 1984). Thus it is argued that equilibrium prices are themselves regulated by commodity values. Two general arguments have been levelled at the Marxist position (see Steedman, 1977). The first is a charge of redundancy: once the techniques of production and either the wage rate or rate of profit are known, equilibrium prices can be determined without recourse to the labour theory of value. The second criticism is more fundamental. Steedman (1977) among others, notably Samuelson (1971), has claimed that there is no direct relationship between commodity values and their respective equilibrium prices. An accusation of inconsistency in the labour theory of value, that is often made in association with Steedman's second criticism, is easily refuted once the restrictive assumptions underlying his examples are revealed (see Farjoun, 1984 and Albarracin, 1984).

In general it is possible to calculate equilibrium prices in the manner suggested by Steedman (1977). Steedman's approach however, unlike that of Marx (1967), fails to explain the origin of profits and the mechanism by which surplus value is extracted from labour power. Most important, Steedman provides no indication of how the value added is divided between wages and profits. To explain the derivation of equilibrium prices one is forced to examine the distribution of value for this is logically prior to the determination of prices. (A number of additional criticisms of the neo-Ricardian position are outlined in Mandel and Freeman, 1984.)

There are two objections to Steedman's second argument. Firstly, regardless of the transformation issue, the labour theory of value provides useful insights into the capitalist mode of production that are not provided by an examination of prices alone (see Shaikh, 1981). Secondly, a number of formal solutions to the so called transformation problem have been provided. Seton (1957) provides an excellent review of the early and central arguments in this debate. A solution more consistent with Marx's own work is provided by Shaikh (1977). These "solutions" however are all suspect to the extent that they require a potentially arbitrary identity be imposed on the value-price relationship.

It should be clear from the above that the connection between values and prices has not been satisfactorily resolved. It is claimed here, after Farjoun and Machover (1983), that the above debate is fundamentally misguided, resting as it does on the unrealistic assumption that the rate of profit is equal in all sectors of the economy and on the erroneous supposition that such a state is representative of a competitive capitalist economy.

In reality rates of profit are never uniform across all sectors of the economy, even over relatively long periods as the data in Chapter 7 reveal. Farjoun and Machover (1983) do not rely on this empirical evidence to dismiss the transformation issue. Their argument rests with the legitimacy of the assumption of uniform profit rates, claiming that a state of equilibrium characterisd by a uniform rate of profit is not a theoretically coherent construct that reflects the real logic of capitalist competition (1983, p.16).

Two objections are raised by Farjoun and Machover against the uniformity assumption, one mathematical and one economic. The mathematical objection is that in general it is not possible to capture the behaviour of a system by assuming that the movement of its parts has reached an average (1983, p.29). The economic objection is that the assumption negates competitive forces that tend to push apart the rate of profit in different sectors. To assume uniform profits, or only a tendency towards uniformity, is to eliminate the drive of capitalists to seek competitive advantages over one another. However, it is precisely this competition that is invoked to produce uniformity in the first place. The type of equilibrium claimed above is one in which all forces have been removed, not merely those that are exogenous to the system.

The implications of the above rejection of the assumption of uniform rates of profit need to be stressed. Firstly, equilibrium prices no longer have any meaning. The only prices that exist are market prices. Secondly, the labour theory of value becomes indispensible as a tool to understanding the determination of these market prices. (This is explained in the following section.) Thirdly, all arguments of Steedman (1977) concerning the redundancy of the labour theory of value are dismissed. In the following section, a new relationship between values and market prices based on Farjoun and Machover (1983) is outlined.

3.5 Expected Prices

Having rejected the concept of equilibrium prices, Farjoun and Machover (1983) do not abandon the sphere of prices altogether. Noting that the price of any individual commodity may vary with each transaction, they argue most strongly for the use of probabilistic methods to represent the vagaries of the "free market", and demand that prices, wages and the rate of profit be treated as random variables determinate only up to a probability distribution.

The central variable in the probabilistic political economy of Farjoun and Machover is the ratio of price to the labour content of a particular commodity, what they term the commodity's specific price. In order to define the specific price (Ψ) of commodities as a random variable a sample space of a given length, say h, is delimited. The sample space consists of all transactions in the period h that involve commodities other than labour-power. Each transaction is weighted by the labour content of the commodity traded. Thus,

$$\Psi_k = P_k/\lambda_k \quad \text{for transaction } k$$

where P_k is the price paid for the commodity in the kth transaction:

λ_k is the labour content of the commodity in the k^{th} transaction.

The mean or expected value of Ψ is

$$E(\Psi) = E(P/\lambda) :$$

where E denotes the expected or mean value defined over all

transactions of all commodities in a period h.

Farjoun and Machover (1983, pp.112-119) prove that for the set of all commodites sold in a period h

$$E(\Psi) = E(P/\lambda)$$

$$= E(V/\lambda) + E(S/\lambda) :$$

where $E(V/\lambda) = \sum_k V_k \; / \; \sum_k \lambda_k$:

$$E(S/\lambda) = \sum_k S_k \; / \; \sum_k \lambda_k:$$

and where $\sum_k V_k$ is the sum of wages paid in period h for the

production of all commodities:

$\sum_k S_k$ is the sum of profits gained in period h in the

production of all commodities.

Define $e^{*} = E(S/V)$

$$= \sum_k S_k \; / \; \sum_k V_k \, ,$$

then, $E(\Psi) = E(V/\lambda) + E(S/V) \, . \, E(V/\lambda))$

$$= E(V/\lambda) \, . \, (1+e^{*}).$$

$E(V/\lambda)$ represents the total wage bill of period h divided by the total labour content of all commodities sold or produced in that period. (In equilibrium Farjoun and Machover assume that the quantities produced and sold are the same.) This term is then equivalent to the wage per unit of labour embodied in the commodities of period h. Let us denote the average wage rate by W. Thus,

$$E(\Psi) = W(1+e^{*}). \tag{3.14}$$

Equation 3.14 is the expected ratio of price to value calculated over all commodities produced and sold in period h. This ratio is equal to the product of the average unit wage and one plus the price rate of exploitation.

Extending the arguments of Farjoun and Machover (1983), it is possible to derive the specific price of all commodities in the model economy. Assume that in a given period the number of transactions of each commodity j, for j=1,...,n is very large. For each commodity, a sample space consists of all transactions k of that particular commodity type in a production period. The specific price of commodity j in transaction k is therefore

$$\Psi_{jk} = P_{jk}/\lambda_j \ , \qquad \text{for } j=1,\ldots,n:$$

where P_{jk} is the price paid for commodity j in transaction k:

λ_j is the labour value of commodity j.

The value of a given commodity type does not vary between transactions. The mean or expected price of commodity j is

$$E(\Psi_j) = E(P_j/\lambda_j), \quad \text{for } j=1,\ldots,n. \tag{3.15}$$

Note though, that all units of the same commodity type have the same labour value, regardless of the technique used to produce them and the nature of the transaction in which they are exchanged on the market. Thus λ_j can be calculated in the manner described in Section 3.2.2. $E(\lambda_j)$ is therefore degenerate and is precisely the labour value of commodity j. Equation 3.15 can now be rewritten as

$$E(\Psi_j) = E(P_j)/\lambda_j \ . \tag{3.16}$$

Following the arguments above, for j=1,...,n:

$$E(\Psi_j) = E(V_j)/\lambda_j + E(S_j)/\lambda_j:$$

where $E(V_j)/\lambda_j = \sum_k V_{jk}/\lambda_j$:

$$E(S_j)/\lambda_j = \sum_k S_{jk}/\lambda_j:$$

and where $\sum_k V_{jk}$ is the sum of wages paid in the sample period for the production of commodity j:

$\sum_k S_{jk}$ is the sum of profits gained in the sample period

for the production of commodity j.

Defining $e_j^* = E(S_j)/E(V_j)$, again for j=1,...,n

$$= \sum_k S_{jk} / \sum_k V_{jk},$$

then,

$$E(\Psi_j) = E(V_j)/\lambda_j + (E(S_j)/E(V_j)).(E(V_j)/\lambda_j)$$

$$= (E(V_j)/\lambda_j).(1+e_j^*) \ . \qquad (3.17)$$

Letting $E(V_j)/\lambda_j = W_j$ represent the ratio of total wages paid in a given period for the production of all commodities of type j (for j=1,...,n) to the total value of all commodities of type j produced in the same period, equation 3.17 becomes

$$E(\Psi_j) = W_j(1+e_j^*) \ , \quad \text{for } j=1,...,n. \qquad (3.18)$$

Equation 3.18 is the expected ratio of the price of commodity j to the labour value of commodity j. This ratio is equal to the product of the average unit wage paid for a unit of labour engaged in the production of commodity j and one plus the price rate of exploitation in department j. Combining equation 3.16 and equation 3.18

$$E(P_j) = W_j(1+e_j^*).\lambda_j \;, \qquad \text{for } j=1,\ldots,n, \tag{3.19}$$

and therefore

$$E(P_j) = \lambda_j. \tag{3.20}$$

Equation 3.20 thus shows that in a competitive economy where commodity prices are not fully determined, the best estimate of a commodity's market price is given by its labour value. This relation takes the place of the famous transformation algorithm, where equilibrium prices are replaced by expected prices.

Using the above equations a set of performance measures for the economy can now be defined in terms of expected prices. These measures are the price counterparts of those developed in Section 3.2.3. Combining equations 3.9 and 3.20 and equations 3.12 and 3.20, the expected price rate of profit for an industry j and for the economy as a whole are defined respectively as

$$\pi_{pj} = \frac{\sum_{i=1}^{n} (1-\lambda_i d_{ij}) l_j x_j \; W_i(1+e_i^*)}{\sum_{i=1}^{n} [\lambda_i k_{ij} x_j + \alpha_j \lambda_i d_{ij} l_j x_j / t_j] \; W_i(1+e_i^*)} \; : \tag{3.21}$$

for $i=1,\ldots,n$: and

$$\pi_{p} = \frac{\sum_{j=1}^{n} \sum_{i=1}^{n} (1-\lambda_i d_{ij}) l_j x_j \; W_i(1+e_i^*)}{\sum_{j=1}^{n} \sum_{i=1}^{n} [\lambda_i k_{ij} x_j + \alpha_j \lambda_i d_{ij} l_j x_j / t_j] \; W_i(1+e_i^*)} \; : \tag{3.22}$$

for $i,j=1,\ldots,n$.

Equations 3.12 and 3.22 are equivalent: for the economy as a whole, the value rate of profit is equal to the price rate of profit. In a closed economy, even though all commodities will not be sold at their expected price, the sum of the deviations of commodity prices from their respective values will not create any additional profit or impose any additional cost. Equations 3.9 and 3.21 are not necessarily equal however, for the value and price rates of profit in the same industry may vary. This is explained in the following section.

3.6 Competition

It is assumed throughout this thesis that markets are competitive and that the firms which comprise an industry produce an homogeneous commodity that is sold in the same market. Competition through product innovation is ignored, though it could be treated simply by expanding the range of industries that define the economy.

In this economy, firms compete in two arenas, in production and in the market. In production, firms in a single industry compete by minimising average costs. In their attempts to decrease costs, each firm may choose a different technique of production that may be distinguished on the basis of unit cost. Thus, some firms will be able to produce a given commodity more efficiently (at lower unit cost) than others. In Section 3.2 it was argued that commodity values are determined by the socially necessary labour time required for their production. Each commodity therefore has a unique value, though the costs involved in the production of a particular commodity will vary between firms as the techniques of production vary. If commodities sell at prices equal to their respective values, then the rate of profit will vary between firms in one industry as the unit costs of production differ. Those firms producing with more efficient techniques of production will appropriate profit at the expense of those producing with less efficient techniques.

If commodities exchange at their expected prices (values), there is no transfer of profit between firms in different industries. In this case, the value rate of profit will be equal to the price rate of profit for each industry. If however, commodities are not assumed to exchange at their respective expected prices, profit will be transferred between firms in the same industry and between firms in different industries. This is competition in the market. If firms can obtain inputs of either capital or labour at prices below the expected or market rate, then their costs of production will be lower in price terms than in value terms. If these same firms can sell their output at the expected or market rate, then they will enjoy a price rate of profit in excess of the value rate anticipated in production. In addition, if these same firms sell their output at prices above the market rate, then their rate of profit will be higher still. Equally, those firms and industries that are not competitive in the market may realise a rate of profit lower than expected, or lower than their value rate of profit.

If industries and/or regions contain firms that are more or less efficient than average in the market, then profit will be transferred from firms in the less efficient industries and regions, to those in the more efficient industries and regions. In this way, the price rate of profit in a particular industry or a particular region may be increased or decreased below the value rate. This transfer of value may occur if the rate of profit is the same or is different between firms and thus it does not constitute a form of unequal exchange.

3.7 Conclusion

This chapter provides a definition of commodity values and a consistent set of measures of economic performance. These definitions are more general than those of Morishima (1973). Measures of commodity values that are based upon the identification of equilibrium prices (the transformation of values to prices) are shown to be fundamentally misguided, resting on the fallacious assumption that a competitive economy in equilibrium is characterised by uniform rate of profit across all sectors. Building on the work of Farjoun and Machover (1983), it is argued that commodity prices should be treated as random variables. The expected price of a commodity is then shown to be equal to its labour value. This concept of expected prices proves useful in developing the concept of capitalist competition, allowing two forms of competition to be identified: competition in production, or attempts by firms to minimise average costs: and competition in the market, or attempts by firms to obtain inputs at prices below values, and to sell output at prices above the market rate. The accounting framework outlined in this chapter informs the subsequent theoretical and empirical sections of this thesis.

CHAPTER 4

ECONOMIC GROWTH WITH NO TECHNICAL CHANGE

4.1 Introduction

This chapter examines the process of economic growth in a capitalist economy characterised by the absence of technical change. Although no real economy is constrained by the total absence of technological improvement, such a system reveals useful information about the limits to economic growth. The model is restricted to two sectors for this is sufficient to reveal the necessary relations for the accumulation of capital. Technical change introduces complications to the simple model of growth outlined here and is thus examined in the following chapter.

Economic growth, or accumulation, is defined as an expansion of the forces and relations of production (Wright, 1979). Thus, accumulation involves an increase in the value of capital engaged in productive activity and the expansion and deepening of capitalist relations of production to encompass the provision of a greater variety of goods and services and the control of a larger number of workers.

Section 2 of this chapter examines Marx's scheme of balanced accumulation. Marx's model is shown to rest on a number of untenable assumptions. The third section of the chapter outlines a more general growth model, building on the accounting framework developed in Chapter 3. Relations between departments of production, investment behaviour and the determinants of changes in the real wage are discussed in this section. Section 4 examines some of the characteristics of the growth path of the economy and in Section 5, the key results of the chapter are outlined.

4.2 Marx's Model of Expanded Reproduction

The model of expanded reproduction developed by Marx is generally formatted in terms of a two-department scheme: department 1 producing the means of production and department 2 producing consumption goods. The scheme of accumulation shows the patterns of demand and supply for both commodities

$$C_{1(t)} + V_{1(t)} + S_{1(t)} = C_{1(t+1)} + C_{2(t+1)} : \qquad (4.1)$$

$$C_{2(t)} + V_{2(t)} + S_{2(t)} = V_{1(t)} + V_{2(t)} + (1-b_{(t)})(S_{1(t)} + S_{2(t)}) : \qquad (4.2)$$

where the subscripts 1 and 2 refer to the department of production:

C represents the constant capital costs of production:

V represents the variable capital costs of production:

S represents the surplus value produced:

1-b denotes the proportion of the surplus consumed unproductively.

The accounts cover a period of production of one year say. The subscript t denotes the year.

Equation 4.1 shows that in a balanced or equilibrium growth model, the value of output of capital goods in year t must equal the value of capital goods consumed by both departments in the following year. Equation 4.2 shows that the value of consumption goods produced in year t must equal the value of goods consumed by labourers in period t+1 and by capitalists in period t.

The Marxist model of accumulation presented above has several important features. First, there is no fixed capital in the reproduction formulae: all capital is fully used up in a single round of production. Second, Marx assumed that the capital advanced in each department of production has the same rate of turnover. These two assumptions allowed Marx to express performance measures of the economy, such as the rate of profit, in the terms of equations 4.1 and 4.2. When these assumptions are relaxed, the rate of profit, value composition of capital, rate of exploitation and other measures of an economy's performance, cannot be formulated simply in terms of the value of productive inputs. In the more general case, the service life of fixed capital and the length of the production period have a significant influence on these variables and must be included in their calculation (see Chapter 3).

Third, Marx assumed that sufficient reserves of labour always exist to meet the requirements of the economy, regardless of the rate of growth and demand for labour. A corollary of this assumption, implicit in the scheme of expanded reproduction, is that the real wage and the value of labour power are constant. Desai (1979) seems to overlook this assumption and is at pains to rationalise Marx's model of balanced accumulation with his more famous statements on crisis and the cyclical character of growth in capitalist economies. With an unlimited supply of labour however there is no reason to expect the balanced path of accumulation of Marx's reproduction model to falter.

Fourth, the characterisation of investment behaviour in Marx's growth model is quite peculiar. Indeed, Marx argued that the pace of growth is determined by the actions of capitalists in the department producing the means of production. Marx claimed that capitalists in department 1 consume a fixed proportion of their surplus and use the rest for accumulation. Investment by capitalists in department 2 is thus determined by the availability of capital inputs. Morishima (1973) and later Desai (1979) have shown that this assumption leads to the convergence of growth rates in the two departments after only one round of production. This is shown below. Let the value of output of each department be denoted by Y_j such that

$$C_{j(t)} + V_{j(t)} + S_{j(t)} = Y_{j(t)} \qquad \text{for } j = 1,2.$$

Denote by b_j the proportion of the surplus that is saved for accumulation in department j. Then

$$b_{j(t)}S_{j(t)} = (C_{j(t+1)} + V_{j(t+1)}) - (C_{j(t)} + V_{j(t)}) \;. \qquad (4.3)$$

The change in output of department j between successive rounds of production is

$$Y_{j(t+1)} - Y_{j(t)} = C_{j(t+1)} + V_{j(t+1)} + S_{j(t+1)} - C_{j(t)} + V_{j(t)} + S_{j(t)} \;.$$

From Chapter 3,

$$\pi_{j(t)} = S_{j(t)}/(C_{j(t)} + V_{j(t)}) \; .$$

Therefore,

$$S_{j(t)} = \pi_{j(t)}(C_{j(t)} + V_{j(t)}) \text{ and}$$

$$Y_{j(t+1)} - Y_{j(t)} = (1+\pi_{j(t+1)})(C_{j(t+1)} + V_{j(t+1)}) - (1+\pi_{j(t)})(C_{j(t)} + V_{j(t)}) \; .$$

With constant techniques of production and a fixed wage, the time subscripts on the rate of profit can be dropped, and the rate of growth of department j is

$$\Delta Y_j/Y_{j(t)} = \frac{(C_{j(t+1)} + V_{j(t+1)}) - (C_{j(t)} + V_{j(t)})}{C_{j(t)} + V_{j(t)}} \; .$$

Substituting from equation 4.3

$$\Delta Y_j/Y_{j(t)} = \frac{b_{j(t)}S_{j(t)}}{C_{j(t)} + V_{j(t)}} \; .$$

Thus, the growth rate in department j is

$$g_{j(t)} = b_{j(t)}\pi_j . \qquad (4.4)$$

By assumption, $b_{1(t)} = b_{1(t+n)}$ for all n and so $g_{1(t)} = g_{1(t+n)}$ for all n.

In department 2 however, the rate of accumulation may vary between rounds of production because of the availability of capital goods. To ensure that all department 1's output is sold after the tth production period, department 2 must alter its stock of capital goods by the amount

$$b_{2(t)}\pi_{2(t)}C_{2(t)} = Y_{1(t)} - C_{1(t+1)} - C_{2(t)}. \tag{4.5}$$

To show this, rewrite equation 4.5 as

$$(1+g_{2(t)})\ C_{2(t)} = Y_{1(t)} - C_{1(t+1)}\ ;$$

and given $(1+g_{2(t)})\ C_{2(t)} = C_{2(t+1)}$, then

$$C_{2(t+1)} = Y_{1(t)} - C_{1(t+1)}$$

which is equivalent to equation 4.1. Rewriting equation 4.5,

$$g_{2(t)} = \frac{1}{C_{2(t)}}\ (Y_{1(t)} - C_{1(t+1)}) - 1.$$

We need to prove that the growth rate of department 2 in period t+1 is equal to the growth rate in department 1 (which is assumed constant), or, $g_{2(t+1)} = g_{1(t)}$. It is easily established that

$$Y_{1(t+1)} = (1+g_{1(t)})\ Y_{1(t)}$$

and that

$$Y_{2(t+1)} = (1+g_{2(t)})\ Y_{2(t)}.$$

Given that

$$g_{2(t+1)} = \frac{1}{C_{2(t+1)}} (Y_{1(t+1)} - C_{1(t+2)}) - 1$$

then,

$$g_{2(t+1)} = \frac{1}{C_{2(t+1)}} [(1+g_{1(t)})(Y_{1(t)} - C_{1(t+1)})] - 1$$

$$= \frac{1}{C_{2(t+1)}} [(1+g_{1(t)}) C_{2(t+1)}] - 1$$

$$= 1 + g_{1(t)} - 1$$

So $g_{2(t+1)} = g_{1(t)}$ Q.E.D.

Finally, it is emphasised that the scheme of expanded reproduction is firmly entrenched in the value sphere. There is no consideration of markets, prices or the circulation of capital. This point is important for it is not clear who advances capital in the form of money to purchase the entire output of both departments and so permit accumulation in Marx's model. The issue of realisation is not dealt with explicitly in this thesis.

4.3 A More General Model of Economic Growth

Using the accounting framework outlined in Chapter 3 it is possible to identify the conditions that characterise simple reproduction (no growth) and expanded reproduction (accumulation) in capitalist economies. Such analysis is useful for it reveals the relationships that must obtain between the departments of production, however unlikely, to ensure that the economy is in equilibrium. An understanding of such conditions is necessary before examining departures from equilibrium and their repercussions throughout the economic system. The growth model outlined is quite different from that of Marx (1967): capital may move between sectors; department 1 does not dictate the pace of growth and the real wage varies in response to the state of the labour market.

The more general model of expanded reproduction is again developed in terms of a two department scheme: department 1 producing the means of production and department 2 producing consumer goods. In this scheme there is no separate department producing fixed capital inputs, and for simplicity, the real wage is assumed equal throughout the economy.

The growth model is represented by the following equations. Only new terms will be discussed in this section. The output of the capital and consumer goods departments are given by equations 4.6 and 4.7 respectively:

$$x_{1(t)} = a_{11}(1+g_{1(t)})x_{1(t)} + a_{12}(1+g_{2(t)})x_{2(t)}: \qquad (4.6)$$

$$x_{2(t)} = D_{(t+1)}L_{(t+1)} + F_{(t)}: \qquad (4.7)$$

where $L_{(t+1)} = l_1(1+g_{1(t)})x_{1(t)} + l_2(1+g_{2(t)})x_{2(t)}: \qquad (4.8)$

and $F_{(t)} = (1-b_{(t)})(1-\lambda_2 D_{(t)})\, L_{(t)}. \qquad (4.9)$

a_{1j}, for j=1,2, represents the aggregate capital input coefficient in department j:

λ_i, for i=1,2, represents the unit value of the aggregate capital good and the unit value of the aggregate consumer good respectively:

D denotes the real wage which is the same in both departments:

L denotes the total labour employed:

F represents consumption by capitalists from profits.

Equations 4.6 and 4.7 describe the physical flows of the two commodities in the simple model economy. They represent the conditions that must hold for the levels of production in each department to be consistent with the demand for both types of commodities. If these equalities do not hold then there will be overproduction or underproduction of both types of commodities and the process of accumulation will be disrupted.

Rearranging equation 4.6, the relative sizes of the two departments that ensures balanced growth is

$$x_{1(t)} = \frac{a_{12}(1+g_{2(t)})x_{2(t)}}{1-a_{11}(1+g_{1(t)})} = Zx_{2(t)}. \qquad (4.10)$$

Once the output of department 2 is fixed, the complementary output of capital goods is determined by the capital input coefficients and the growth rates in the two departments. The rate of growth measures the rate of expansion of the inputs to production. The economy-wide growth rate is determined by the average rate of profit and by the proportion of profits used to finance accumulation:

$$g_{(t)} = b_{(t)}\pi_{(t)} \; . \tag{4.11}$$

From the preceding chapter, the economy-wide rate of profit is an average of the departmental profit rates

$$\pi_{j(t)} = \frac{(1-\lambda_2 D_{(t)}) l_j x_{j(t)}}{\lambda_1 a_{1j} x_{j(t)} + \lambda_2 D_{(t)} l_j x_{j(t)}} \qquad \text{for } j=1,2. \tag{4.12}$$

Note that the rate of profit is defined for a single turnover period, that the length of the turnover period is assumed to be equal in both departments and that it is constant through time.

To complete the model, a method of adjusting the real wage is required along with a means of allocating investment between the two departments. The real wage is examined first. The rate of change of the real wage is assumed to be a positive, increasing and continuous function of changes in the employment rate. That is,

$$\Delta D/D_{(t)} = f[\Delta(L_{(t)}/N_{(t)})] \; , \qquad f' > 0 \tag{4.13}$$

where $N_{(t)}$ denotes the size of the available labour force.

The total new investment each turnover period, the additional capital advanced in the economy as a whole, is

$$I_{(t)} = b_{(t)}(1-\lambda_2 D_{(t)}) \; L_{(t)} \; .$$

The proportion of this new capital invested in each department depends on the relative rates of profit in the two departments:

$$\psi_{1(t)} = R \; (\pi_{1(t)}/\pi_{2(t)})$$

and $\psi_{2(t)} = 1 - \psi_{1(t)}$.

It is assumed that $1 > \lambda_2 D_{(t)}$, and thus $\pi_{1(t)}, \pi_{2(t)} > 0$, for all t. R is a positive, increasing and continuous function of the ratio of departmental profit rates. The total new investment in department j in period t is

$$I_{j(t)} = \psi_{j(t)} b_{(t)} (1-\lambda_2 D_{(t)}) L_{(t)} :$$

and the departmental growth rate is

$$g_{j(t)} = \frac{\psi_{j(t)} b_{(t)} (1-\lambda_2 D_{(t)}) L_{(t)}}{C_{j(t)} + V_{j(t)}} . \qquad (4.14)$$

The above set of equations characterise the two department growth model. In the following sections some of the properties of this model are examined.

4.3.1 Balanced Growth Equilibrium

The economy is in a state of equilbrium if the departmental rates of profit are constant, that is, if

$$\Delta\pi_j/\pi_{j(t)} = 0 \qquad \text{for } j = 1,2.$$

If the departmental rates of profit are constant then the economy-wide profit rate $\pi_{(t)}$ is also constant over time and equal to $\pi^*_{(t)}$.

(If a variable has no department subscript it is economy-wide. The * symbol denotes the value of a variable in equilibrium.) Given (1-b), the propensity to consume from profits, the equilibrium growth rate in the economy is

$$g^*_{(t)} = b_{(t)}\pi^*_{(t)} \text{ , and if b is constant over time}$$

then,

$$g^*_{(t)} = b\pi^*_{(t)} \; .$$

The constancy of the rate of profit in the economy also implies that the real wage is fixed, that is,

$$\Delta D/D_{(t)} = 0 \; :$$

for without technical change, the rate of profit is a function of the real wage. In turn, the constancy of the real wage implies, after equation 4.13, that the rate of employment $L_{(t)}/N_{(t)}$ does not vary. A constant rate of employment itself implies that

$$(L_{(t+1)}/N_{(t+1)}) - (L_{(t)}/N_{(t)}) = 0 \text{ , or:}$$

$$\frac{L_{(t+1)}N_{(t)} - L_{(t)}N_{(t+1)}}{N_{(t+1)}N_{(t)}} = 0 \text{ , or:}$$

$$L_{(t+1)}N_{(t)} = L_{(t)}N_{(t+1)} .$$

Thus,

$$(L_{(t+1)}/L_{(t)}) = (N_{(t+1)}/N_{(t)}) \text{ , or:}$$

$$1 + \Delta L/L_{(t)} = 1 + \Delta N/N_{(t)} :$$

and therefore,

$$\Delta L/L_{(t)} = \Delta N/N_{(t)}.$$

Given that

$$\Delta L_{(t)} = (l_1 x_{1(t+1)} + l_2 x_{2(t+1)}) - (l_1 x_{1(t)} + l_2 x_{2(t)}):$$

$$= l_1 \Delta x_{1(t)} + l_2 \Delta x_{2(t)}:$$

and

$$x_{1(t)} = Zx_{2(t)}:$$

where Z is defined in equation 4.10, then

$\Delta x_{1(t)} = Z\Delta x_{2(t)}$, if b and thus g remain constant.

From the equations above,

$\Delta L_{(t)} = (l_1 Z + l_2)\ \Delta x_{2(t)}$: and therefore

$$\Delta L/L_{(t)} = \frac{(l_1 Z + l_2)\ \Delta x_{2(t)}}{(l_1 Z + l_2)\ x_{2(t)}} :$$

$$= \Delta x_2/x_{2(t)}.$$

Thus,

$\Delta L/L_{(t)} = \Delta x_2/x_{2(t)}$: and

$\Delta N/N_{(t)} = g_L = \Delta L/L_{(t)} = \Delta x_2/x_{2(t)} = g_{2(t)}$.

If $\Delta L/L_{(t)}$ and $g_{2(t)}$ are constant, then with no technical

change,

$$g_{1(t)} = g_{2(t)} = g_L . \qquad (4.15)$$

Equation 4.15 states that in the equilibrium defined by constant rates of profit, with fixed production techniques, the growth rates of both departments are equal to one another, constant through time and equal to the natural rate of growth of the labour supply. Such a pattern of accumulation is termed a "golden-age" growth path.

4.4 Stability

The previous section outlined some of the characteristics of an equilibrium growth path for the two-department economy. The existence, uniqueness and stability of this growth path are proved in Appendix 1. In this section a less formal examination of the characteristics of the growth path are examined.

4.4.1 Characteristics of Different Equilibria

For the economy as a whole an equilibrium is characterised by a rate of growth of productive inputs that is equal to the natural rate of growth of the labour force. Without technical change the demand for labour in the economy will continue to match the increase in supply.

This balance in the labour market manifests itself in a fixed rate of employment and a constant real wage. In turn the rate of profit, which is only a function of the real wage in this model, will also remain fixed. With the additional constraint of a constant propensity to save, the growth rate of the economy and thus the rate of growth of the inputs to production will not deviate from the equilibrium rate.

With fixed coefficients of production, movements from one equilibrium position to another result from exogenous shocks to the economy. In this model these shocks are limited to changes in the natural rate of growth of the labour force. Appendix 1 proves that the growth path is stable. Thus, if the economy is "pushed" from an equilibrium growth path, forces endogenous to the economy will tend to restore equilibrium. The relations that produce stability are now examined in a less formal fashion.

Assume that the rate of growth of the labour force increases from g_L to g_L^+. Section 4.3 showed that the rate of growth of the supply of labour is the economy's equilibrium growth rate. Therefore, we are interested in how the economy moves from an existing equilibrium growth path g_L^* to a new equilibrium growth path g_L^{*+}, where

$$g_L^{*+} > g_L^* = b\pi^* \ .$$

From the original equilibrium, an increase in the rate of growth of the labour force will drive down the rate of employment, for the growth in the demand for labour is initially determined by the old equilibrium rate. Therefore, if the growth rate of the labour force rises in production period t then the rate of employment will fall between period t and period t+1:

$$(L/N)_{(t+1)} < (L/N)_{(t)}.$$

From equation 4.13, changes in the real wage are a positive function of the employment rate. The decrease in the rate of employment therefore causes the real wage to fall between period t and period t+1. In turn, the reduction in the real wage increases the rate of exploitation in period t+1 and also increases the rate of profit, for $\partial\pi/\partial D < 0$. If the savings propensity of the capitalist class remains fixed, or alternatively if it is specified as a positive function of the rate of profit, then the rate of growth of the economy and thus the demand for labour must rise after period t+1, for

$$g_{(t+1)} = b\pi_{(t+1)} > b\pi^{*} = g_{(t)}.$$

The rate of growth of the economy will continue to increase as long as the rate of expansion of the labour supply exceeds the rate of expansion of the demand for labour. This inequality cannot persist however, for increases in the profit rate and thus the rate of economic growth, will move the economy to the new equilibrium g_L^{*+}. These arguments also hold for the opposite case where the rate of growth of the economy outstrips the rate of increase in the supply of labour, that is, when the exogenously determined rate of growth of the labour supply slows.

Different equilibrium growth rates are characterised by variations in several indicators of economic performance. By definition

$g^{*+} \neq g^{*}$, and thus

$$\pi^{*}b = g^{*} \neq g^{*+} = \pi^{*+}b \ . \qquad (4.16)$$

If the savings propensity remains constant then equation 4.16 implies that the rate of profit cannot be the same in the old equilibrium and the new equilibrium. With fixed techniques of production, changes in the rate of profit result from changes in the real wage. From equation 4.16 therefore, if $\pi^{*} \neq \pi^{*+}$, then, by implication $D^{*} \neq D^{*+}$. Different equilibrium states therefore are not only characterised by different growth rates, but also by different rates of profit and by different wage rates. The direction of change in the rate of profit and thus the real wage depend on the direction of the change in the supply of labour and thus the economy's growth rate. If the labour force increases more rapidly than previously, the new equilibrium wage will be lower than the old equilibrium wage and the new equilibrium profit rate will be higher than previously. Conversely, if the rate of growth of the labour force falls, the real wage rises and the equilibrium profit rate falls. These arguments imply that the rate of unemployment will vary between equilibria, with that rate moving in the same direction as the rate of profit.

4.4.2 Equilibrium and Stability Within Individual Departments

Focusing on the two departments of production rather than the economy as a whole reveals significant differences in both how the economy moves from one equilibrium to another and in the characteristics of the different equilibrium positions. In equilibrium, the economy-wide rate of profit π^* is given by g^*/b. With π^* known, D^* can be estimated and then the departmental profit rates obtained from equation 4.12.

In general, the departmental profit rates will not equal π^* for techniques of production will vary between the two sectors. Although $\pi^* \neq \pi^{*+}$ the departmental growth rates must be equal in equilibrium (see section 4.3) This equality implies that

$$\frac{I_{1(t)}}{C_{1(t)} + V_{1(t)}} = \frac{I_{2(t)}}{C_{2(t)} + V_{2(t)}} : \qquad (4.17)$$

where I is defined above.

Equation 4.17 states that if the economy is on a balanced growth path then the relative rates of profit in the two departments must be equal to the ratio of capital stocks in the two departments. This equality ensures that each department receives new capital for accumulation in proportion to the size of its capital stock, thereby guaranteeing equal rates of growth in both sectors of the economy.

For the economy to move from one equilibrium growth rate to another, the distribution of capital between departments must be altered. To see this, let the growth rate move from g^* to g^{*+}. Thus, from section 4.3

$$g_1^{*+} = g_2^{*+} = g^{*+} \neq g^* = g_1^* = g_2^* .$$

Equation 4.10 then shows that the relative sizes of the two departments must change between equilibrium growth rates, for

$$\frac{x_1^{*+}}{x_2^{*+}} = \frac{a_{12}(1+g^{*+})}{1-a_{11}(1+g^{*+})} \neq \frac{a_{12}(1+g^{*})}{1-a_{11}(1+g^{*})} = \frac{x_1^{*}}{x_2^{*}} . \tag{4.18}$$

Any alteration in the equilibrium growth rate must cause the relative sizes of the two departments to change.

Equation 4.17 shows that in equilibrium the growth rates of the two departments are constant and equal to one another. Equation 4.18 shows that the rates of growth in the two departments must change and change in different directions if the economy moves from one equilibrium growth path to another equilibrium growth path. It remains in this section to outline how the transfer of capital between sectors occurs. The arguments are presented in the following examples.

Let the equilibrium growth rate of the economy in period t be g^*. The rate of growth of the labour force in period t is g_L^{*+} ($>g^*$). Thus, a new equilibrium growth path for the economy has been specified. The real wage in period t is D^* and the rate of profit is π^*. The scale of department 1 in period t+1 is $a_{11}(1+g^*)x_{1(t)}$, and the scale of department 2 in period t+1 is $a_{12}(1+g^*)x_{2(t)}$. For department 2 to sell all its output in period t+1 it is required that

$$x_{2(t+1)} = D^* L_{(t+2)} + (1-b)(1-\lambda_2 D^*)L_{(t+1)}.$$

However, with the increase in the supply of labour and the rate of unemployment, the real wage falls from D^* in period t to $D_{(t+2)}$ in period t+2, and therefore

$$x_{2(t+1)} = D^*L_{(t+2)} + (1-b)(1-\lambda_2 D^*)L_{(t+1)} > D_{(t+2)}L_{(t+2)} + (1-b)(1-\lambda_2 D_{(t+1)})L_{(t+1)}.$$

With the reduction in the real wage, consumption by workers in period t+1 is less than anticipated, for

$$D^*L_{(t+1)}(1+g^*) > D_{(t+1)}L_{(t+1)}(1+g^*) .$$

Consumption by capitalists in period t+1 is greater than anticipated because of the increase in the rate of profit. If capitalists consume the full value of the additional surplus department 2 will be able to sell all its output in period t+1. However, the propensity to consume from profits is fixed and thus a portion of the extra surplus is destined for additional accumulation. Therefore, department 2 does not sell all its output in t+1.

The value of goods remaining unsold in department 2 must be subtracted from the surplus obtained in order to calculate the rate of profit realised by department 2 in period t+1. Department 1 does not experience any realisation problems with the increase in the equilibrium growth rate. Thus, in period t+1

$$[\pi_{1(t+1)}/\pi_{2(t+1)}] > [\pi_1^*/\pi_2^*] .$$

If capital is allocated between departments on the basis of their relative rates of profit, then the increased rate of profit in department

1 relative to department 2, will lead to higher levels of investment in the capital goods sector. From equation 4.18, if the equilibrium growth rate increases, then capital must indeed flow from department 2 to department 1. This flow of capital will continue until the capital stocks in both departments are complementary in size given the new growth rate. When the correct relative scales of production have been established, the growth rates in the two departments will converge and remain constant through the relation given by equation 4.17. In the new equilibrium, markets for both types of commodities will clear, for the rate of growth of output and thus the inputs to production will again equal the rate of growth of the labour supply and therefore the real wage will remain constant.

Again these arguments hold for the converse case. If the rate of growth of the labour supply and the equilibrium growth rate decrease, then the real wage will rise and the potential rate of profit will fall. In this case department 1 would experience overproduction problems and the relative rates of profit in the two departments would channel capital to the consumer goods department.

The above arguments may be modified by the movement of capital between departments, for different labour input coefficients coupled with changing output levels will alter the demand for labour. In general though, capital will move from department 1 to department 2 if the equilibrium rate growth rate is reduced, and capital will shift from department 2 to department 1 if the equilibrium growth rate increases.

4.5 Conclusion

Four conclusions are drawn from the analysis in this chapter. Firstly, an equilibrium growth path for the model economy exists. The equilibrium growth rate is equal to the rate of growth of the labour supply. With a specific technology, propensity to save and rate of growth of the labour force, the growth path is unique and it is stable. Stability ensures that if the rate of growth of the labour force changes, forces endogenous to the system will adjust the economy's growth rate until it is once again equal to the growth rate of the labour force. In equilibrium there are no tendencies for the rate of growth of the economy and the rate of growth of the labour force to diverge. Equilibrium in this model does not require that the profit rates be equal in both departments of production.

Secondly, if the economy moves from one equilibrium growth path to a higher equilibrium rate of growth, following an increase in the rate of growth of the labour supply, the new equilibrium will be characterised by a lower rate of employment and thus a lower real wage, a higher rate of profit and an increase in the relative scale and relative rate of profit in department 1 compared with department 2. Conversely, if the economy shifts to a lower equilibrium rate of growth, the new equilibrium will be characterised by a higher rate of employment and thus a higher real wage, a lower rate of profit and an increase in the relative scale and relative rate of profit in department 2 compared with department 1.

Thirdly, with no technical change, the growth rate of the economy is determined by the rate of growth of the labour force. Although individual departments may exceed the rate of growth of the labour force for short periods between equilibria, in the long-run, the economy cannot grow faster or slower than the labour force. With a constant rate of growth of the labour force, an economy can enjoy higher levels of growth only if the labour supply is augmented. Two means by which the supply of labour can be increased are immigration and the attraction of labour from non-capitalist sectors of the economy. Economies can also escape the strictures imposed by the supply of labour by adopting technical changes that reduce the labour required to produce a given level of output. The issue of technical change is addressed in the following chapter.

Fourthly, without technical change there is no tendency for the economy described in this chapter to experience secular falls in the rate of profit and thus economic crises. The economy may however undergo periods of overproduction in one of the two departments as it moves from one equilibrium growth path to another. These will be shortlived as economic forces alter the relative rates of profit in the two departments and channel investment away from the sector that is overproducing. If the economy moves to a higher equilibrium growth path, overproduction will temporarily occur in the consumer goods department as wages fall, and with a fixed propensity to invest, capitalist consumption will not increase sufficiently to clear the market. If the growth rate of the labour force slows, overproduction will occur in the capital goods sector. In this case, wages rise and the rate of profit falls. With a fixed savings propensity, the market for capital goods does not clear. Reductions in the rate of profit in department 1 relative to department 2 alter the distribution of capital between the two departments and restore equilibrium.

CHAPTER 5

THE EFFECTS OF TECHNICAL CHANGE ON ECONOMIC GROWTH

5.1 Introduction

The impact of technical change on economic growth and profitability is by no means clear. Some technical changes undoubtedly increase the rate of profit, yet others may cause that rate to fall. In addition, while certain types of innovation increase the rate of profit and thus the potential rate of accumulation for the individual firm, the "long run" impact of such changes on the economy as a whole are less easy to ascertain. Does technical change offer capitalist economies the possibility of continued uninterrupted accumulation, or does it inevitably lead to crisis? This chapter examines the effect of technical change on the rate of profit.

The technique of production is the concrete form taken by the labour process in a given instance (Harvey, 1982). Techniques vary between firms producing the same commodity and between firms producing different commodities. Techniques of production also change through time. In a broad sense, the technology employed in the production of a commodity can be defined by the inputs to production and how they are combined, by the organisation of the labour force and by the relations between direct producers and the owners of the means of production. Technical change is characterised by any alteration in the material form of the productive forces and social relations of production. For the moment however, technical change is defined in the rather restrictive sense as any change in the value of the input coefficients in either department of production. For convenience, the two department model of the economy introduced in Chapter 4 will continue to be used.

This chapter is organised in seven sections. Following the introduction, a brief review of previous Marxist work on technical change is provided. The limits of this work are made clear. Sections 3 and 4 respectively, examine the effect of technical change on commodity values and expected prices when the real wage is assumed constant. In Section 5, the model of the economy presented in the last chapter is extended to examine the effects of technical change on the real wage. Section 6 analyses the central results of the model, while section 7 concludes the chapter discussing the implications of these results.

5.2 Literature Review: Technical Change and the Rate of Profit

The analysis of technical change in the Marxist literature is almost always couched in discussion of economic crisis and the related arguments about the falling rate of profit. (For a review of this literature see the URPE crisis reader, 1978.) In this section, discussion is limited to an examination of the tendency of the rate of profit to fall. This is not a review of Marxian crisis theory.

The value rate of profit is given after Marx (1967) as

$$\pi_V = \frac{S}{C+V},$$

$$= \frac{S/V}{C/V + 1},$$

$$= \frac{[(1-\lambda_2 D)L]/[\lambda_2 DL]}{[\lambda_1 K]/[\lambda_2 DL] + 1},$$

and where the terms are defined as previously. (The turnover time of capital is ignored in this model.) This equation was used by Marx to explain the tendency of the rate of profit to fall within the capitalist mode of production. In essence he argued that the pace of accumulation would outstrip the natural rate of growth of the labour force and exert pressure for wages to rise. In a bid to combat wage increases, capitalists replace labour by machinery, increasing the technical composition of capital (K/L). This form of technical change was supposed to raise the value composition of capital (C/V). Unless counteracted by increases in the rate of exploitation of labour (S/V), a rising value composition of capital will force down the rate of profit.

These arguments triggered the long-standing debate as to whether or not technical change causes the rate of profit to fall. Early discussion was centred on two questions. Firstly, do increases in the technical composition of capital necessarily raise the value composition of capital? Secondly, do technical changes that raise the value composition of capital also increase the rate of exploitation sufficiently to offset the tendency of the rate of profit to fall? These questions are addressed in turn below.

Mattick (1969) and Yaffe (1973) argue that the rate of profit must fall as the logical result of technical changes that raise the composition of capital. In support of his claim Yaffe presents a simple model of accumulation and shows that with a constant rate of exploitation and a fixed labour input, accumulation is characterised by a rising value composition of capital. Hodgson (1974), Bell (1977) and Wright (1979) all point out however that the value composition of capital will not necessarily move in the same direction as the technical composition. While criticising Yaffe for assuming what he seeks to prove, Hodgson (1974, p.62) correctly notes that even though the ratio K/L may rise through changing the methods of production, the same technical change will alter the unit values of capital and consumer goods. There is nothing to guarantee that such changes will not lower the unit value of capital goods faster than consumption goods, decreasing the ratio λ_1/λ_2, and thus offsetting the tendency of the value composition of capital to rise.

More recently, Lebowitz (1982) has contested this latter point. He argues that while technical change decreases the unit values of labour power and manufactured capital goods, capital cannot wholly transform the production of raw materials. Lebowitz thus regards "nature" as a barrier to accumulation and on this platform asserts that: "...the very growth of capital necessarily generates a tendency for the rate of profit to fall." (1982, p.12).

Blaug (1960) offers a more fundamental criticism of Marx's model. Questioning the tenability of the rising technical composition of capital itself, he argues that capital-saving technical changes may be just as likely as those of a labour-saving kind. Sweezy (1970) and Wright (1979) though misguided in their attempts to refute Blaug's claim with empirical evidence, do correctly point out that Blaug fails to provide a reason why technical change should predominantly take a capital-saving form. In contrast, if the model of accumulation is broadened to take into account a limited supply of labour and rising wages, the predominance of labour-saving technical changes can be readily explained (see Webber, 1987c).

The answer to the second question posed above appears just as elusive as the answer to the first. Both Yaffe (1973) and Wright (1979) maintain that the greater the rate of exploitation, the less effective it is in combatting the effect of increases in the composition of capital on the rate of profit. Thus, it is argued that the rate of profit must eventually fall. Though not necessarily incorrect, Yaffe and Wright fail to show under precisely what conditions a technical change would or would not alter the rate of exploitation sufficiently to offset the change in the composition of capital. They certainly do not show that the tendency for the rate of profit to fall will ultimately prevail.

In general, one learns little of the relationship between technical change and the rate of profit from these early debates. For the most part this stems from the failure to clarify the relations between the physical coefficients of production, the values of inputs and their respective prices. The work referenced above is conducted solely in value terms. There are at least three ramifications of this.

Firstly, a precise definition of what constitutes a technical change is lacking. Such a definition must be based on the physical (input-output) coefficients of production, for these determine the values (and in conjunction with the real wage, the prices) of inputs and thus the elements of the rate of profit. If one remains at the level of values, direct comparison of terms like the value composition of capital and the rate of exploitation is impossible. The failure to reduce the values of inputs to their physical roots is significant, for changes in the value of certain productive inputs may not be the result of technical changes, while some real technical change may be masked by a consequent adjustment of the value of inputs.

Secondly, no distinction can be made between the types of technical change that would or would not be adopted by firms in a competitive economy. This argument is important for the types of innovation that can be introduced depend crucially on the nature of the market. Furthermore, different types of technical changes may affect the rate of profit in different ways. The ambiguity between values and prices also precludes an examination of the micro-economic determininats of firm behaviour with respect to the adoption of new technologies.

Thirdly, this early debate did not separate the effects of technical change per se on the rate of profit, and changes in that rate that might for example result from higher wages. It is shown later that this distinction is extremely important.

The exposure and development of Okishio's theorem, particularly by Roemer (1978, 1979 and 1981), denotes a significant break in the examination of the relationship between technical change and the rate of profit. Prior to Roemer's work, with the notable exception of Morishima (1973), the investigation of technical change was for the most part non-mathematical and often somewhat "religious" in nature, with adherents of competing views combing Marx's original writings for supporting text (see

Mattick, 1969; Yaffe, 1972 and Bell, 1977). Okishio (1961) raised the level of inquiry by framing the debate in a more formal mathematical framework. This format is shared by most recent analyses of technical change (see van Parijs, 1980; Roemer, 1981 and Webber, 1982b and c).

Okishio's (1961) work was a major advance precisely because he overcame the criticisms listed above. Okishio defined techniques of production in physical terms using capital and labour input coefficients. He also consistently adhered to the framework of equilibrium prices to explain the logic of innovation and the types of new techniques that would be introduced by firms in a competitive environment. Using these tools Okishio proved that if real wages remain constant, technical changes that are cost reducing at existing prices must raise the equilibrium rate of profit. The proof of Okishio's theorem is central to the arguments of this chapter and is briefly reviewed here.

Assume that an economy produces two types of commodity, a capital good and a consumption good. From Chapter 3, the equilibrium prices of the two commodities are given as

$$p_1 = (1+\pi_p)(p_1a_{11} + p_2Dl_1) \; : \qquad (5.1)$$

$$p_2 = (1+\pi_p)(p_1a_{12} + p_2Dl_2) \; . \qquad (5.2)$$

Equations 5.1 and 5.2 can be rewritten in matrix notation as

$$\mathbf{p} = (1+\pi_p)\mathbf{pM} \; , \qquad (5.3)$$

where $\mathbf{p}$ is a 1x2 element row vector of equilibrium prices:

$\mathbf{M}$ is a 2x2 matrix of capital and labour input coefficients.

Columns 1 and 2 of the matrix **M** represent the techniques of producing commodities 1 and 2 respectively. Letting

$$p_2D = 1 \tag{5.4}$$

be numeraire, it can be shown that there exist a unique (up to a scalar) π_p and vector **p** that satisfy equations 5.3 and 5.4. Equation 5.3 can be rewritten as

$$\eta \mathbf{p} = \mathbf{pM} : \tag{5.5}$$

where η (= $(1+\pi_p)^{-1}$) is the eigenvalue and **p** the eigenvector of matrix **M**. If **M** is non-negative and indecomposable, then by the Perron-Frobenius theorems (see Pasinetti, 1977), there exists a largest η that is associated with a vector **p** that is strictly positive. Furthermore, the eigenvalue η is a positive and strictly increasing function of the elements of **M**.

Okishio argued that in a competitive market capitalists will adopt a technical change only if it is cost reducing at current prices. That is if,

$$p_1a_{1j}^* + p_2Dl_j^* < p_1a_{1j} + p_2Dl_j , \quad \text{for } j=1,2, \tag{5.6}$$

where the asterisk indicates the new technique of production. Such a technical change is termed viable (Roemer, 1981). In a competitive market (with equilibrium prices) any viable innovation will immediately raise the rate of profit for the adopting firm. The inequality of rates of profit is then supposed to induce the movement of capital from firms with a low rate of profit to those with a high rate of profit, thus restoring equilibrium by adjusting prices. It is not clear however, whether the new equilibrium rate of profit will be higher or lower then the old. Okishio's theorem asserts that after prices have changed, the new equilibrium rate of profit will increase. This is shown below.

Before technical change, equilibrium prices satify equations 5.3 and 5.4. In equilibrium

$$\frac{\mathbf{pm}_j}{p_j} = \eta , \qquad \text{for } j = 1,2 : \tag{5.7}$$

$$= \frac{1}{1+\pi_p} :$$

where $\mathbf{m}_j$ is the j^{th} column of matrix $\mathbf{M}$ and $\mathbf{pm}_j$ represents the cost of producing commodity j:

π_p is the equilibrium rate of profit.

A new technique for producing any commodity, say commodity 1, is cost reducing at current prices if

$$\frac{\mathbf{pm}_1^*}{p_1} < \eta . \tag{5.8}$$

Equations 5.6 and 5.8 are equivalent. Replacing $\mathbf{m}_1$ of the matrix $\mathbf{M}$ with the new technique $\mathbf{m}_1^*$, and renaming the input coefficient matrix $\mathbf{M}^*$, Roemer (1981) proves that

$$\min_j \frac{pm_j^*}{p_j} < \eta^* < \max_j \frac{pm_j^*}{p_j} .$$

Then, given that

$$\min_j \frac{pm_j^*}{p_j} = \frac{pm_l^*}{p_l} < \frac{pm_l}{p_l} = \max_j \frac{pm_j^*}{p_j} = \eta ,$$

it follows that $\eta^* < \eta$ and therefore, $\pi_p^* > \pi_p$. Okishio's theorem thus establishes that viable technical changes must increase the equilibrium (price) rate of profit.

Van Parijs (1980) claims Okishio's theorem settles the relationship between technical change and the profit rate and provides an "obituary" for Marx's theory of the falling rate of profit. Shaikh (1983), and Alberro and Persky (1979), try to resurrect that theory, criticising Okishio for failing to incorporate fixed capital in his model. Shaikh argues that in a world with fixed capital firms may seek to protect their profit margins rather than their profit rates, and in so doing they may willingly adopt technical changes that lower their own rate of profit. The assumption that firms will intentionally act to lower their own rate of profit is criticised by van Parijs (1980) and Roemer (1981).

Shaikh's arguments are by no means a negation of Okishio's claims, for Roemer (1981) shows that in a more general model incorporating fixed capital and retaining the assumptions of Okishio, viable technical changes will still increase the rate of profit.

Roemer's extension of Okishio's model is not complete however, for he fails to recognise that the inclusion of fixed capital may have a significant impact on the timing of innovation. Though a new production technique may exist, in a world with fixed capital it will not be cost reducing for a given firm until the present discounted cost of production associated with the new technology outweighs the present discounted cost of production with the existing technique plus the cost of scrapping the existing fixed capital if it is not completely depreciated. But in a competitive market, firms may not be able to afford to postpone the introduction of cost cutting techniques. Alberro and Persky (1979) continue this argument noting that if the succession of viable innovations is sufficiently rapid, the rate of profit realised by firms might fall even though the expected rate of profit rises. The shortfall in profits again being due to the scrapping of fixed capital before it is fully depreciated. While not disproving Roemer's arguments, the inclusion of fixed capital in Okishio's model, even with all its assumptions, casts some shadow of doubt on the necessity of the rate of profit to rise.

Perhaps the most serious weakness of Okishio's claims are the assumptions upon which his arguments rest. The two most important assumptions are that the real wage remains fixed and that equilibrium prices prevail in the economy. Arguments against the use of equilibrium prices were made in chapter 3. In the following section the central tenets of Okishio's theorem are outlined within the framework of an expected price model. In the remainder of this section attention is focused on the assumption of constant real wages.

Roemer (1978 and 1981) proves that if the relative share of profits and wages is maintained following labour-saving technical change, then the rate of profit will fall. Though the assumption of constant relative shares is arbitrary, as Roemer himself acknowledges, this result shows that Okishio's theorem is not as robust as van Parijs (1980) claims. Webber (1982b and c) broadens this argument, taking into account the scale of production and the issue of realisation. He shows that labour-saving technical changes must be accompanied by rising real wages in order to avoid problems of overproduction (assuming that unsold commodities cannot be exported). Thus, capitalists face a lower rate of profit if they do not increase the real wage, and they reduce the rate of profit if they do increase it.

Stripping the assumptions from Okishio's theorem exposes it to the various forms the contradictions inherent in the capitalist accumulation process can take. Though Okishio's methods and his result are very important it is essential to appreciate what his theorem proves and the conditions under which his results obtain. In an economy where the rate of profit is not equalised between all firms, where real wage adjustments may depend on the demand and supply of labour and thus technical change, and where all firms do not automatically produce the precise amount of output required, Okishio's theorem tells us little about the real impact of technical change. The effects of technical change in a less restrictive model are now examined.

5.3 The Effect of Technical Change on Commodity Values

From Chapter 3, the unit values of the capital good and the consumer good, in the two department model of production, can be defined in terms of the physical input coefficients as

$$\lambda_1 = \frac{l_1}{1-a_{11}} \tag{5.9}$$

$$\lambda_2 = \frac{a_{12}l_1}{1-a_{11}} + l_2 . \tag{5.10}$$

It is assumed that $a_{1j} > 0$ and $l_j > 0$, for $j=1,2$, and that $1-a_{11} > 0$. Therefore, commodity values are positive. Using equations 5.9 and 5.10, the effect of changes in the coefficients of production on value-based measures of economic performance can be examined. For simplicity, measures of the turnover time of capital are ignored throughout this chapter.

The examination begins by showing the impact of technical changes on commodity values using the following partial derivatives:

$$\frac{\partial\lambda_1}{\partial a_{11}} = \frac{l_1}{(1-a_{11})^2} > 0:$$

$$\frac{\partial\lambda_2}{\partial a_{11}} = \frac{a_{12}l_1}{(1-a_{11})^2} > 0:$$

$$\frac{\partial\lambda_1}{\partial a_{12}} = 0:$$

$$\frac{\partial \lambda_2}{\partial a_{12}} = \frac{l_1}{(1-a_{11})} > 0:$$

$$\frac{\partial \lambda_1}{\partial l_1} = \frac{1}{(1-a_{11})} > 0:$$

$$\frac{\partial \lambda_2}{\partial l_1} = \frac{a_{12}}{(1-a_{11})} > 0:$$

$$\frac{\partial \lambda_1}{\partial l_2} = 0:$$

$$\frac{\partial \lambda_2}{\partial l_2} = 1.$$

These derivatives establish the following two facts. Firstly, if more capital or labour is required to produce a unit of the capital good, then the value of all commodities produced in the economy will rise. Secondly, should more capital or labour be required to produce a unit of the consumption good, then the value of that good will increase and the value of the capital good will be unaffected.

Combining equations 5.9 and 5.10 with information on the scale of production in the two departments allows the effect of technical changes on the value composition of capital to be ascertained. This analysis is important for increases in the value composition of capital exert a downward pressure upon the rate of profit and thereby influence the pattern of growth. The value composition of capital in department j is defined as

$$\frac{C_j}{V_j} = \frac{\lambda_1 a_{1j} x_j}{\lambda_2 Dl_j x_j} :$$

$$= \frac{l_1 a_{1j}}{[a_{12} l_1 + (1-a_{11}) l_2] Dl_j}, \quad \text{for } j=1,2 : \qquad (5.11)$$

where x_j, for j=1,2, represents the number of units of commodity

j produced in a given round of production.

The economy-wide value composition of capital is a weighted average of the individual department compositions, the weight being determined by the relative sizes or the scale of production in each.

Taking the partial derivatives of equation 5.11 with respect to the input coefficients for both departments 1 and 2, the following signs are found:

$$\frac{\partial(C_1/V_1)}{\partial a_{11}} = \frac{DR + a_{11} Dl_2}{(DR)^2} > 0: \qquad (5.12a)$$

where $R = a_{12} l_1 + (1-a_{11}) l_2$

$$\frac{\partial(C_2/V_2)}{\partial a_{11}} = \frac{Da_{12} l_1 l_2^2}{(DRl_2)^2} > 0: \qquad (5.12b)$$

$$\frac{\partial(C_1/V_1)}{\partial a_{12}} = \frac{-a_{11} l_1}{(DR)^2} < 0: \qquad (5.12c)$$

$$\frac{\partial(C_2/V_2)}{\partial a_{12}} = \frac{D(1-a_{11})l_1 l_2^2}{(DRl_2)^2} > 0: \tag{5.12d}$$

$$\frac{\partial(C_1/V_1)}{\partial l_1} = \frac{-Da_{11}a_{12}}{(DR)^2} < 0: \tag{5.12e}$$

$$\frac{\partial(C_2/V_2)}{\partial l_1} = \frac{Da_{12}(1-a_{11})l_2^2}{(DRl_2)^2} > 0: \tag{5.12f}$$

$$\frac{\partial(C_1/V_1)}{\partial l_2} = \frac{-Da_{11}(1-a_{11})}{(DR)^2} < 0: \tag{5.12g}$$

$$\frac{\partial(C_2/V_2)}{\partial l_2} = \frac{-D[a_{12}l_1 + 2(1-a_{11})l_2}{(DRl_2)^2} < 0. \tag{5.12h}$$

Equations 5.12a, 5.12d, 5.12e and 5.12h, establish that increases in the capital input coefficient and decreases in the labour input coefficient (changes that increase the technical composition of capital) raise the value composition of capital in the departments in which these technical changes occur. Furthermore, an increase in the capital input coefficient of department 1 also raises the value composition of capital in the consumer goods department and thus the economy as a whole (5.12a and b). Similarly, a decrease in the labour input coefficient of department 2, the consumer goods department, raises the value composition of capital in department 1 and therefore the entire economy (5.12g and h).

Equations 5.12c and 5.12f prove that technical changes that reduce the technical composition of capital can lead to increases in the value composition. For example, a technical change that decreases the capital input coefficient in department 2 causes the value composition of capital in department 1 to rise. Likewise, a decrease in the labour input coefficient in department 1 causes the value composition of capital in department 2 to increase. These results show that the arguments of Blaug (1960), Sweezy (1970) and Yaffe (1973) are overly simplistic.

Though an increase in the capital input coefficient of department 2 raises the value composition of capital in that department, such a change does not necessarily raise the value composition of capital in the economy. In this case, a rise in the economy-wide value composition of capital may be offset by a reduction in that measure in department 1 (5.12c). The effect of changes in the capital input coefficient of department 2 on the value composition of capital of the whole economy depends on the techniques of production and the scale of production in the two departments. Similar arguments can be made with respect to changes in the labour input coefficient of department 1. The movement of the economy's value composition of capital in this case also depends on techniques of production in the two departments. These arguments clarify as far as possible the impact of technical changes of various sorts upon the value composition of capital. It remains now to examine the effects of such changes on the rate of exploitation and the value rate of profit.

The rate of exploitation is defined as

$$e = \frac{(1-\lambda_2 D)}{\lambda_2 D} : \tag{5.13}$$

$$= \frac{(1-a_{11}) - RD}{RD} . \tag{5.13a}$$

The rate of exploitation as defined in equation 5.13 is assumed to be the same for both departments and for the economy as a whole. Therefore a technical change of a particular type will have the same effect on this variable throughout the economy. Again, the effects of technical change are evaluated by taking the partial derivatives of equation 5.13a with respect to the input coefficients in both departments of production.

$$\frac{\partial e_j}{\partial a_{11}} = \frac{-Da_{12}l_1}{(DR)^2} < 0 \text{ , for } j=1,2:$$

$$\frac{\partial e_j}{\partial a_{12}} = \frac{-D(1-a_{11})l_1}{(DR)^2} < 0 \text{ , for } j=1,2:$$

$$\frac{\partial e_j}{\partial l_1} = \frac{-D(1-a_{11})a_{12}}{(DR)^2} < 0 \text{ , for } j=1,2:$$

$$\frac{\partial e_j}{\partial l_2} = \frac{-D(1-a_{11})^2}{(DR)^2} < 0 \text{ , for } j=1,2.$$

The above derivatives show that an increase in any of the coefficients of production will reduce the rate of exploitation and thus exert a negative influence on the rate of profit.

The impact of technical change on the rate of profit is now evaluated. Like Roemer (1981) after Okishio (1961), the analysis here examines the effect of technical change on the rate of profit independent of changes in the real wage. In addition, this examination takes no account of problems of overproduction in the economy. It is therefore the value complement to Roemer's work in the sphere of equilibrium prices, examining movements in the potential maximum rate of profit (rather than the real rate), that arise from alterations in the techniques of production. Webber (1982b) examines this same issue but he makes the mistake of assuming that the rate of exploitation and the real wage remain constant as techniques change. However, if the real wage is held constant then technical change must alter the rate of exploitation. The work here is important for it resolves the arguments about the effects of technical change upon the value rate of profit.

It is possible to evaluate the implications of changes in the input coefficients on the rate of profit in two ways. The first is to combine the information from the anaysis of the effects of such changes on the value composition of capital and the rate of exploitation. The second, is to examine the effects of technical change directly on the rate of profit. The second route is preferred for it is shown that additional information is gained.

The value rate of profit is defined for each department of production as

$$\pi_j = \frac{(1-\lambda_2 D) l_j x_j}{(\lambda_1 a_{1j} + \lambda_2 D l_j) x_j}, \text{ for } j=1,2. \tag{5.14}$$

Taking the partial derivatives of equation 5.14 with respect to the input coefficients:

$$\frac{\partial \pi_1}{\partial a_{11}} = \frac{-1 + Dl_2}{(a_{11} + DR)^2} < 0 , \quad \text{for } 1 > Dl_2 : \tag{5.14a}$$

$$\frac{\partial \pi_2}{\partial a_{11}} = \frac{-a_{12} l_1 l_2}{(a_{12} l_1 + DRl_2)^2} < 0 : \tag{5.14b}$$

$$\frac{\partial \pi_1}{\partial a_{12}} = \frac{-Dl_1}{(a_{11} + DR)^2} < 0 : \tag{5.14c}$$

$$\frac{\partial \pi_2}{\partial a_{12}} = \frac{-(1-a_{11}) l_1 l_2}{(a_{12} l_1 + DRl_1)^2} < 0 : \tag{5.14d}$$

$$\frac{\partial \pi_1}{\partial l_1} = \frac{-D}{(a_{11} + DR)^2} < 0 : \tag{5.14e}$$

$$\frac{\partial \pi_2}{\partial l_1} = \frac{-(1-a_{11}) a_{12} l_2}{(a_{12} l_1 + DRl_2)^2} < 0 : \tag{5.14f}$$

$$\frac{\partial \pi_1}{\partial l_2} = \frac{-D + Da_{11}}{(a_{11} + DR)^2} < 0 , \quad \text{for } a_{11} < 1 : \tag{5.14g}$$

$$\frac{\partial \pi_2}{\partial l_2} = \frac{a_{12} l_1 (1 - \lambda_2 D)}{(a_{12} l_1 + DRl_2)^2} > 0 . \tag{5.14h}$$

From inequalities 5.14a through 5.14h, and maintaining the assumptions of a constant real wage and no realisation problems, the following conclusions can be drawn. Firstly, technical changes that increase (decrease) the capital input coefficient in either department of production cause the value rate of profit to fall (rise) in both departments and thus the economy as a whole (5.14a-d). Secondly, a technical change that increases (decreases) the labour input coefficient in department 1 also causes a decrease (increase) in the profit rate throughout the economy (5.14e and f). Thirdly, technical change that increases (decreases) the labour input coefficient in department 2 causes the rate of profit to fall (rise) in department 1 and the rate of profit to rise (fall) in department 2 and thus its effect on the aggregate rate of profit in the economy as a whole is indeterminate.

One other set of results is of interest. It is generally supposed in the literature, at least implicitly (see Mattick, 1969 and Yaffe, 1973), that technical changes that raise (lower) the value composition of capital, and thus tend to depress (increase) the rate of profit, will also raise (lower) the rate of exploitation, and thus tend to raise (lower) the rate of profit. The rate of profit will thus follow the direction imposed by the stronger of these two forces. However, this argument presumes that technical changes move the two key variables in the same direction. The analysis above shows that these arguments depend on the nature of the technical change. For example, technical changes that raise the value composition of capital by increasing the value of any of the input coefficients will always lower the rate of exploitation. In such a case the rate of profit must fall as a consequence of technical change alone, for there is no tendency for the rate of profit to rise. Only those technical changes that cause the value composition of capital to fall as a result of an increase in one of the input coefficients will cause the rate of exploitation to oppose the effect of a falling value composition on the profit rate. Furthermore, in this case, the change in the rate of exploitation will always overwhelm the impact of the value composition of capital on the rate of profit. This finding corroborates the claim of Roemer (1981, p.89) that movements in the rate of exploitation will always offset changes in the composition of capital.

It remains in the following sections of this chapter to relax as far as possible the restrictive assumptions imposed on the analysis above. In the next section, the effects of technical changes on commodity prices are examined. Working with expected prices after Farjoun and Machover (1983), the shortcomings of the equilibrium price framework are overcome.

5.4 The Impact of Technical Change on Expected Prices

The economy being modelled is assumed to be competitive. That is, each commodity type is produced by a large number of individual firms none of which have the ability to set market prices. Without the ability to determine prices, firms compete in two ways. First, they compete in production by trying to minimise costs. Second, firms compete in the market by seeking inputs at prices below the market rate, by selling output at less than market prices and attempting to expand their market share, or by trying to sell their output at prices above the market rate. The uncertainty of the market and the actions of firms in this arena are particularly difficult to model. This thesis avoids these difficulties by focusing on competition in the sphere of production. For the most part, rational behaviour by competitive firms in production can be captured by assuming that all firms attempt to maximise their rate of profit.

Firms make decisions on the basis of prices not values. The investigation of prices therefore permits an understanding of the behaviour of firms that cannot be gained by a study of values alone. An examination of technical change in the price sphere also narrows the field of enquiry for in a competitive market, firms will only adopt technical changes that are cost reducing at existing prices. From this point then only the effects of cost reducing or viable technical changes are studied.

A viable technical change is represented by the following inequality

$$p_1 a^*_{1j} + p_2 Dl^*_j < p_1 a_{1j} + p_2 Dl_j \,, \qquad \text{for } j=1,2:$$

where the * indicates the new technique and all prices referred to are expected prices.

A cost reducing technical change must lower at least one of the coefficients of production. To simplify the investigation, only changes in one coefficient at a time are examined here. In this case any technical change is cost reducing if it decreases the value of one of the coefficients of production (the others remaining unchanged by assumption). In the remainder of this section, the effect of viable technical change upon commodity prices and the price rate of profit are determined.

The introduction of a new technique by a single firm in the economy has repurcussions that reach beyond the firm itself. To examine these repurcussions the impact of technical change on expected prices must be analysed. From Chapter 3, the expected price of a commodity j is

$$E(p_j) = W_j(1+e_j^*)\lambda_j = \lambda_j, \qquad \text{for } j=1,2. \tag{5.15}$$

The effects of cost reducing technical changes on commodity prices are department specific. These effects are discussed below.

Suppose that a firm in department 1 introduces a cost reducing technical change. This firm will face lower costs of production and as a result it will enjoy a higher rate of profit. The technical change introduced will also alter the expected prices of commodities, however negligibly, for e_1, e_2, λ_1 and λ_2 will all change (see Section 5.3).

By definition, the value of a unit of labour-power is less than unity, so cost reducing technical change in department 1 will lower the expected prices of commodities in both departments of production. In contrast, suppose a firm in department 2 introduces a cost reducing technical change. Again the rate of profit for the innovating firm will rise. In this case however, although the price of commodity 2 will fall, the price of commodity 1 will increase, for the rate of exploitation rises in both departments of production but the value of commodity 1 remains unchanged. In both these examples the nature of the technical change, capital-saving or labour-saving does not alter the results. The effect of cost reducing technical changes on commodity prices is thus clear.

While a viable technical change increases the rate of profit for the firm making the innovation, the accompanying change in prices also alters the profitability of competing firms. Innovation by a firm in department 1 for example will reduce the rate of profit for all other firms in the economy. If the innovation occurs in department 2, then all firms in department 1 will experience a slight increase in the rate of profit and the non-innovating firms in department 2 will experience a fall in the profit rate.

5.5 Technical Change, Real Wages and Growth

In the analysis above, the effects of technical change on a number of economic variables were evaluated while the real wage and the scale of production were assumed constant and when realisation problems were assumed away. These assumptions are relaxed in this section. Two questions are examined. Firstly, how does the real wage respond to technical changes of the kinds considered above? Secondly, if the real wage changes following the adoption of new techniques of production, what is the overall effect upon the rate of profit in an economy.

There are many problems in attempting to model the determination of the real wage and changes therein. Unlike other commodities, the exchange value of labour-power depends not only on techniques of production and the state of the market, but also on a complex mixture of forces and wills that shape bargaining between capitalists and workers (Friedman, 1977). In the model outlined below, the real wage is assumed to be a positive function of the rate of employment. This relatively simple specification of the real wage has a good deal of theoretical and empirical support (see Phillips, 1958; Thirlwall, 1970 and Hewings, 1977). Initially, it is assumed that this functional relationship is linear and that a parameter γ, where $0<\gamma<1$, governs the responsiveness of the real wage to changes in the employment rate.

The impact of technological improvement on the economy is identified using the techniques of comparative statics. These techniques are applied to the following set of simultaneous equations that represent the relationships between variables in the model economy. The precise steps involved in this analysis and a complete set of results for all the systems examined can be found in Appendix 2.

$$\pi = \frac{S}{C+V} \quad : \qquad (5.16)$$

$$S = (1-\lambda_2 D)L \quad : \qquad (5.17)$$

$$C = \lambda_1 K \quad : \qquad (5.18)$$

$$V = \lambda_2 DL \quad : \qquad (5.19)$$

$$K = a_{11}x_1 + a_{12}x_2 \quad : \qquad (5.20)$$

$$x_1 = (1+g)K \quad : \qquad (5.21)$$

$$x_2 = DL(1+g) \quad : \qquad (5.22)$$

$$L = l_1x_1 + l_2x_2 \quad : \qquad (5.23)$$

$$D = \frac{\gamma L}{N} \quad : \qquad (5.24)$$

$$\lambda_1 = \frac{l_1}{1-a_{11}} \quad : \tag{5.25}$$

$$\lambda_2 = \frac{a_{12} l_1}{1-a_{11}} + l_2 \ . \tag{5.26}$$

The following assumptions are made with repect to equations 5.16-5.26. First, all equations refer to a single production period. Second, the growth rate of the economy (g) is the same in both departments and it is constant. Third, the rate of growth of the economy is equal to the natural rate of growth of the available labour force (g_L). Fourth, there is no explicit relationship between the rate of profit and the rate of economic growth. Fifth, capitalists do not consume any consumption commodities.

The second of the assumptions above is made for simplicity. Experimentation with a variable growth rate led to a set of results that could not be interpreted. In the absence of a deterministic relation between the rate of profit and the growth rate, the equality in assumption 3 is sufficient to define an equilibrium in equations 5.16-5.26. Assumption 5, like assumption 2, was made for simplification. Allowing capitalist consumption to vary or even be a positive constant sufficiently complicated the system that once more the results could not be readily interpreted.

5.6 Results

The results of performing the analysis outlined above are presented in this section. The effects of changes in the production coefficients are examined in turn, beginning with the labour coefficients. A change in l_1, the labour input coefficient in department 1, the capital goods sector, has the following effect upon the rate of profit:

$$d\pi = \frac{\pi l_2 x_2 K[g-\pi]}{SL(1-a_{11})(1+g)}.dl_1. \qquad (5.27)$$

Thus, a reduction in l_1 will decrease the rate of profit if $g>\pi$; it will increase the rate of profit if $\pi>g$; and it will leave the rate of profit unchanged if $g=\pi$. This result is interpreted using the following differential equation:

$$d\pi = \frac{1}{C/V + 1}.d(S/V) - \frac{S/V}{(C/V + 1)^2}.d(C/V). \qquad (5.28)$$

From equation 5.28, and given that when $\pi=g$, $d\pi=0$, it follows that

$$\frac{d(S/V)}{d(C/V)} = \frac{S/V}{C/V + 1} = \pi .$$

Thus, a technical change does not alter the rate of profit, if the ratio of the change it induces in the rate of exploitation to the change it induces in the value composition of capital is equal to the rate of profit. From Appendix 2, the following results can also be established:

$$d(S/V) = \frac{1}{V}.dS - \frac{S}{V^2}.dV :$$

$$= \frac{l_2\ (x_1-K)}{\lambda_2 V(1-a_{11})}.dl_1: \qquad (5.29)$$

$$d(C/V) = \frac{1}{V}.dC - \frac{C}{V^2}.dV :$$

$$= \frac{Kl_2}{V(1-a_{11})}.dl_1. \qquad (5.30)$$

Equation 5.29 shows that a decrease in l_1 decreases the rate of exploitation in the economy. Such a change tends to depress the rate of profit. Equation 5.30 shows that a reduction in l_1 decreases the value composition of capital. This tends to raise the rate of profit. It was shown above that when $\pi=g$, these opposing forces balance to leave the rate of profit unchanged.

As g varies, the impact of technical change also varies:

$$\frac{d[d(S/V)/d(C/V)]}{dg} = 1. \qquad (5.31)$$

From equation 5.31, an increase in g increases the ratio of the change in the rate of exploitation to the change in the value composition of capital. Thus, if $g>\pi$, a reduction in l_1 decreases the rate of exploitation faster than it decreases the value composition of capital and the rate of profit falls. If $g<\pi$, a reduction in l_1 tends to decrease the value composition of capital faster than the rate of exploitation and the rate of profit rises.

A change in l_2, the labour input coefficient in department 2, has the following effect upon the rate of profit:

$$d\pi = \frac{\pi l_1 x_2 K[\pi - g]}{SL(1-a_{11})(1+g)} . dl_2 \; . \qquad (5.32)$$

Thus, a reduction in l_2 causes the rate of profit to fall if $\pi > g$; it causes the rate of profit to rise if $g > \pi$; and if $\pi = g$, it leaves the rate of profit unchanged. Again these results may be interpreted using equation 5.28. A decrease in the labour coefficient in department 2, has the following impact on the rate of exploitation and the value composition of capital. From Appendix 2:

$$d(S/V) = \frac{1}{V}.dS - \frac{S}{V^2}.dV \; :$$

$$= \frac{\lambda_1(-x_1+K)}{\lambda_2 V}.dl_2 \; : \qquad (5.33)$$

$$d(C/V) = \frac{1}{V}.dC - \frac{C}{V^2}.dV \; :$$

$$= \frac{-\lambda\ KDL}{V^2}.dl_2 : \qquad (5.34)$$

$$\frac{d[d(S/V)/d(C/V)]}{dg} = 1. \qquad (5.35)$$

Equation 5.33 reveals that a reduction in l_2 increases the rate of exploitation, thereby tending to raise the rate of profit. Equation 5.34 shows that a decrease in l_2 raises the value composition of capital, thereby tending to reduce the rate of profit. When $g=\pi$ these forces balance each other and the rate of profit remains unchanged. From equation 5.35 however, as g increases, the rate of change of the rate of exploitation becomes larger, while the rate of change of the value composition of capital remains constant and thus the rate of profit rises.

The economic effects of capital saving technical changes are now examined. Unfortunately, the impacts of a change in the capital input coefficient in sector 1, the capital goods sector, are largely indeterminate (See Appendix 2). It is not clear how a change in the value of a_{11} will effect the rate of profit or its component variables. A change in the value of the capital input coefficient in the consumer goods department has the following effects on the economy:

$$d\pi = \frac{\pi\lambda_1 l_2 x_2^2 K[g-\pi]}{SL[1-a_{11}(1+g)]}.da_{12} . \qquad (5.36)$$

Equation 5.36 establishes that a reduction in a_{12} will cause the rate of profit to fall if $g>\pi$. If $\pi>g$, such a technical change will increase the rate of profit, and if $\pi=g$, the rate of profit will not be affected by the technical change. These results are explained below. From Appendix 2:

$$d(S/V) = \frac{1}{V}.dS - \frac{S}{V^2}.dV :$$

$$d(S/V) = \frac{\lambda_1 l_2[x_1 - K]}{\lambda_2 V a_{12}}.da_{12}: \tag{5.37}$$

$$d(C/V) = \frac{1}{C}.dC - \frac{C}{V^2}.dV :$$

$$d(C/V) = \frac{\lambda_1 l_2 x_2}{\lambda_2 V[1-a_{11}(1+g)]}.da_{12}. \tag{5.38}$$

Equation 5.37 shows that a decrease in a_{12} will decrease the rate of exploitation in the economy. Such a change tends to depress the rate of profit. Equation 5.38 shows that a reduction in a_{12} will decrease the value composition of capital. This tends to raise the rate of profit. It was shown above that when $\pi=g$, these opposing forces balance to leave the rate of profit unchanged.

As g varies, the impact of technical change also varies:

$$\frac{d[d(S/V)/d(C/V)]}{dg} = 1. \tag{5.39}$$

From equation 5.39, an increase in g increases the ratio of the change in the rate of exploitation to the change in the value composition of capital. Thus, if $g>\pi$, a reduction in a_{12} decreases the rate of exploitation faster than it decreases the value composition of capital and the rate of profit falls. If $g<\pi$, a reduction in a_{12} tends to decrease the value composition of capital faster than the rate of exploitation and the rate of profit rises.

5.7 Conclusion

This chapter reviews the Marxist theory of the falling rate of profit. Two generally accepted propositions in this body of theory are shown to be false. Firstly, technical changes that increase the technical composition of capital do not always increases the value composition of capital and thus tend to depress the rate of profit. For example, an increase in the capital input coefficient in the consumer goods department and a decreases in the labour input coefficient in the consumer goods department will cause the technical composition of capital in that department to rise. However, these two types of technical changes, through their impact on commodity prices, will cause the value composition of capital to fall in the same department. Thus, technical changes that increase the capital-labour ratio do not necessarily tend to reduce the rate of profit. Secondly, technical changes that cause the value composition of capital to rise and thus exert a downward force on the rate of profit, are not always countered by increases in the rate of exploitation. In fact, the results here suggest that most types of viable technical change would decrease the rate of exploitation.

Okishio's theorem marks a significant breakpoint in the development of the theory of the tendency of the rate of profit to fall. Okishio (1961) proved that in an economy where real wages are constant and there are no realisation problems, viable technical changes increase the aggregate rate of profit. van Parijs (1980) claimed that Okishio's theorem was robust and that it provides an obituary for Marxian crisis theory and in particular the theory of the falling rate of profit. The central conclusion of this chapter is that when the assumptions upon which Okishio's theorem is based are relaxed, then that theorem is negated. Thus, viable technical change may cause the aggregate rate of profit in an economy to fall. This result suggests that van Parijs' (1980) claim was a little hasty and that the theory of the falling rate of profit may yet prove an important theoretical tool for explaining economic crises.

CHAPTER 6

THE DIRECTION OF TECHNICAL CHANGE

6.1 Introduction

Chapter 5 established that capital-saving technical changes in general cause the aggregate rate of profit in an economy to rise, whereas certain types of labour-saving technical change may cause that rate to fall. The direction of technical change thus exerts an important influence on economic performance. The aim of this chapter is to examine the determinants of the direction of technical change. The chapter is divided into five sections. In Section 6.2, received theory on induced innovation is briefly reviewed. Section 6.3 builds on this literature to offer a simple model of the likely direction of technical change. In Section 6.4 the arguments of this model are empirically assessed using data from the Canadian manufacturing sector. Section 6.5 concludes the chapter, summarising the results of the empirical analysis.

6.2 Induced Innovation: A Brief Review of the Literature

Prior to the late-1950s, technical change was a much neglected area of economic inquiry. Though several studies were made of the process of invention (see Nelson's (1959) early survey), and two notable taxonomies of biased technical change were proposed (by Hicks, 1932 and Harrod, 1948) that were to inform much subsequent discussion, technological progress was largely ignored or at best viewed as exogenous to the economy.

All this was to change however with the publication of studies by Abramowitz (1956), Solow (1957) and others (see Kennedy and Thirlwall, 1972) reporting the causes of economic growth in the United States in the first half of the present century. Abramowitz and Solow found that only approximately 15% of the increase in labour productivity over this time could be attributed to increases in the amount of capital employed per unit of labour. The "residual", some 85% of the increase in per capita output, was attributable to technical change.

Though the results of Abramowitz and Solow were challenged, most notably by Jorgenson and Griliches (1967), it was generally accepted that the "stylised facts" to be explained, following Solow (1957), were large increases in the capital stock and output, a much slower rate of growth of the labour force and relatively constant factor shares. With techniques of production at this time characterised by an elasticity of substitution of less than one (see Arrow et al., 1961), the problem for neoclassical theory was thus to posit the existence of an endogenous mechanism that would control the bias of technical change precisely enough to maintain factor shares.

Hicks (1932) laid the foundations for the theory of induced innovation by distinguishing between factor substitution (movements along a continuous production function) and technical change which was the discovery of new methods of production (movements of the production function). Hicks argued that both input substitution and technical change were influenced by factor prices:

> The real reason for the predominance of labour-saving inventions is surely that which was hinted at in our discussion

> of substitution. A change in the relative prices of the factors of production is itself a spur to invention, and to invention of a particular kind - directed to economising the use of a factor which has become relatively expensive. (Hicks, 1932, p.124)

Hicks' claim was simply that if one input becomes dearer relative to others, firms will search for new techniques of production that use less of the relatively expensive input. Thus, relative factor prices determine the bias of technical change. These arguments received considerable attention through the 1960s. Appeal to relative factor prices was a neat way of endogenising the determinants of the direction of technical change and the mechanism proposed seemed well suited to explain the history of manufacturing in developed economies in the first part of the twentieth century.

These arguments were not without their critics however. Salter (1960) persuasively countered Hicks' thesis claiming that:

> If ... the theory implies that dearer labour stimulates the search for new knowledge aimed specifically at saving labour, then it is open to serious objections. The entrepreneur is interested in reducing costs in total, not particular costs such as labour costs or capital costs. When labour costs rise any advance that reduce total costs is welcome, and whether this is achieved by saving labour or capital is irrelevant. There is no reason to assume that attention should be concentrated on labour-saving techniques, unless, because of some inherent characteristic of technology, labour-saving knowledge is easier to obtain than capital-saving knowledge. (Salter, 1960, pp.43-44.)

Salter's rebuttal of Hicks' argument rests on two pillars. The first is that a change in relative factor prices induces input substitution that restores the equality between the marginal revenues and marginal costs of all inputs, thereby ensuring that all factors are equally expensive. The search for new techniques of production therefore could not be influenced by relative factor prices, for all are "equally dear" at the margin. In

Ferguson's (1969) opinion, this convincingly refutes Hicks' thesis. The second thrust of Salter's rebuttal hinges on the vague notions of research and development that are embodied in these early debates. Assuming that invention and innovation are costless, Salter is quite right to claim that firms will not care how they reduce costs. However, if the research and development of new techniques demands the outlay of resources then the competitive firm will seek to maximise the benefits from this investment. The benefits of research are the reduction in factor requirements multiplied by the prices of the respective factors. These benefits vary as research paths differ in productivity and as factor prices vary. Thus, ceteris paribus, attempts to reduce the inputs of more expensive factors will maximise cost reductions. This is the essence of the induced innovation hypothesis and Salter's arguments do not reduce the veracity of this proposition.

While Fellner (1961) attempted to rescue Hicks' arguments by appealing to the expectations of monopsonist firms, the next major contribution to the theory of induced innovation was the introduction of the Innovation Possibility Frontier (IPF) by Kennedy (1964). Kennedy saw no way round the confusion of factor substitution and technical change engendered by the continuous production function. He thus proposed to scrap the idea of the production function and introduced the IPF as another mechanism that would explain the bias of technical change and also account for the observed constancy of factor shares.

Kennedy's model has the following form. Assume that there are two factors of production, capital and labour that are related to output by a non-specific production function:

$$Y = f\{A(t)K, B(t)L\}$$

where Y denotes output:

K represents capital:

L represents labour.

$\dot{A}(t)/A(t) \equiv a(t)$ is the rate of capital augmentation through technical change and $\dot{B}(t)/B(t) \equiv b(t)$ is the rate of labour augmentation. Next, Kennedy assumes that ε and τ represent the proportion of total costs attributable to capital and labour respectively. Finally, Kennedy assumes that the proportional factor reductions a and b are related by an innovation possibility frontier which has the following characteristics (see Figure 6.1):

$$b = f(a) \qquad (6.1)$$

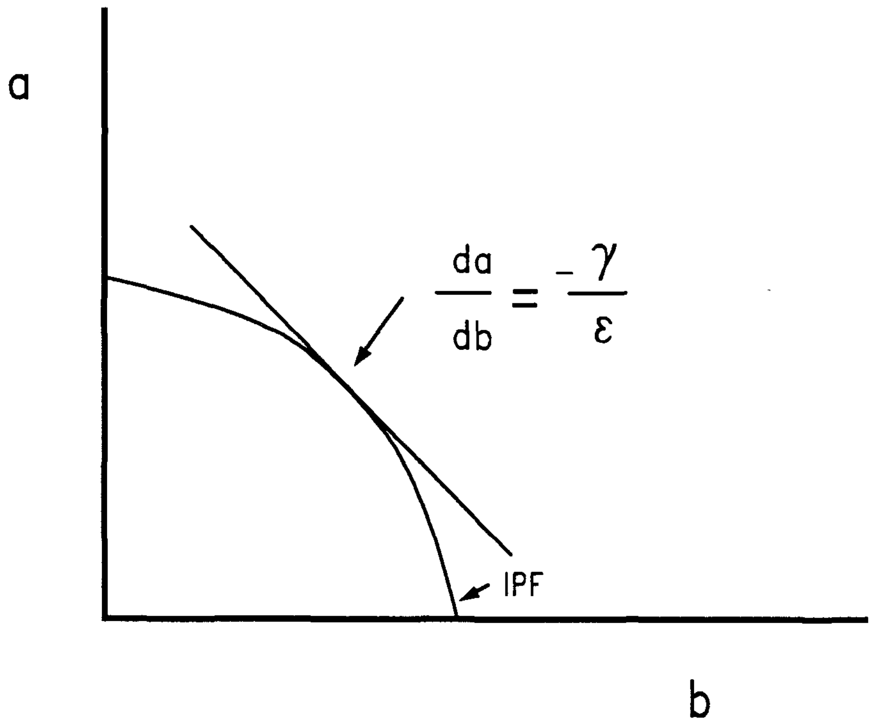
where $f'(a)<0$ and $f''(a)<0$.

Thus, a tradeoff exists between research paths which are capital-saving and those that are labour-saving. Kennedy regarded the form of the IPF as being determined purely by technological characteristics. Each time period, the firm is supposed to search for a new technique that maximises the rate of unit cost reduction (u):

$$u = \varepsilon a + \tau b \ . \qquad (6.2)$$

Thus, the firm aims to maximise Equation 6.2 subject to the constraint 6.1. The equilibrium solution is shown in Figure 6.1 and thus u is maximised where

FIGURE 6.1: KENNEDY'S INNOVATION POSSIBILITY FRONTIER



Source: Adapted from Kennedy (1964)

$\frac{da}{db} = -\frac{\tau}{\varepsilon}$, that is, where the slope of the IPF is equal to the ratio of factor shares. From Figure 6.1 it may be observed that an increase in the relative price of one of the inputs will change the ratio of relative shares (ε/τ) and thus bias the search for new technology toward saving that input. Kennedy's model therefore provides an induced innovation mechanism independent of an explicit production function.

While Kennedy's IPF formed the basis for new models of economic growth incorporating induced innovation (see for example, Dandrakis and

Phelps (1966) and Samuelson (1965)), the concept has not escaped serious criticism. Ahmad (1966) was one of the first critics of Kennedy's induced innovation hypothesis. Redefining a and b in equation 6.1 as absolute rather than proportional factor savings, Ahmad showed that Kennedy's model was not as robust as originally proposed, for in this case the greater the initial use of labour to capital in production, the less likely it is that innovation will take a labour saving tack (1966, p.352). This result of course is opposite to that proposed by Kennedy.

Perhaps the most serious problem with Kennedy's induced innovation model however is the lack of any explanation of the form of the IPF. Stoneman (1983) questions whether the IPF represents technological possibilities as yet undeveloped or whether it should be considered a set of blueprints which the innovating firm can choose from. Noting that resources are not explicitly used for adopting the techniques of the IPF, he concludes that the IPF represents a set of developed techniques. But this begs the question of the origin of the IPF and the determinants of its precise form.

Nordhaus (1973) continues these criticisms calling for an explanation of the characteristics of the IPF and questioning whether or not Kennedy's model really is a statement of induced innovation:

> The true case of induced innovation requires at least two productive activities, production and invention. If there is no invention, then the theory of induced innovation is just a disguised case of growth theory with exogenous technological change. (Nordhaus, 1973, p.210).

Nordhaus further challenged the usefulness of the IPF as a component in a neoclassical growth model with the supposed ability to produce Harrod-neutral technological progress and account for the constancy of factor shares. Nordhaus demonstrates that to achieve such ends it must be assumed that the form of the IPF does not change, that it is not influenced by previous technological choices and that the "natural drift" of invention must be identical to the movement of the IPF over time. Though Kennedy's work has undoubtedly proved very useful, his contribution to the theory of induced innovation is perhaps best summed up by David:

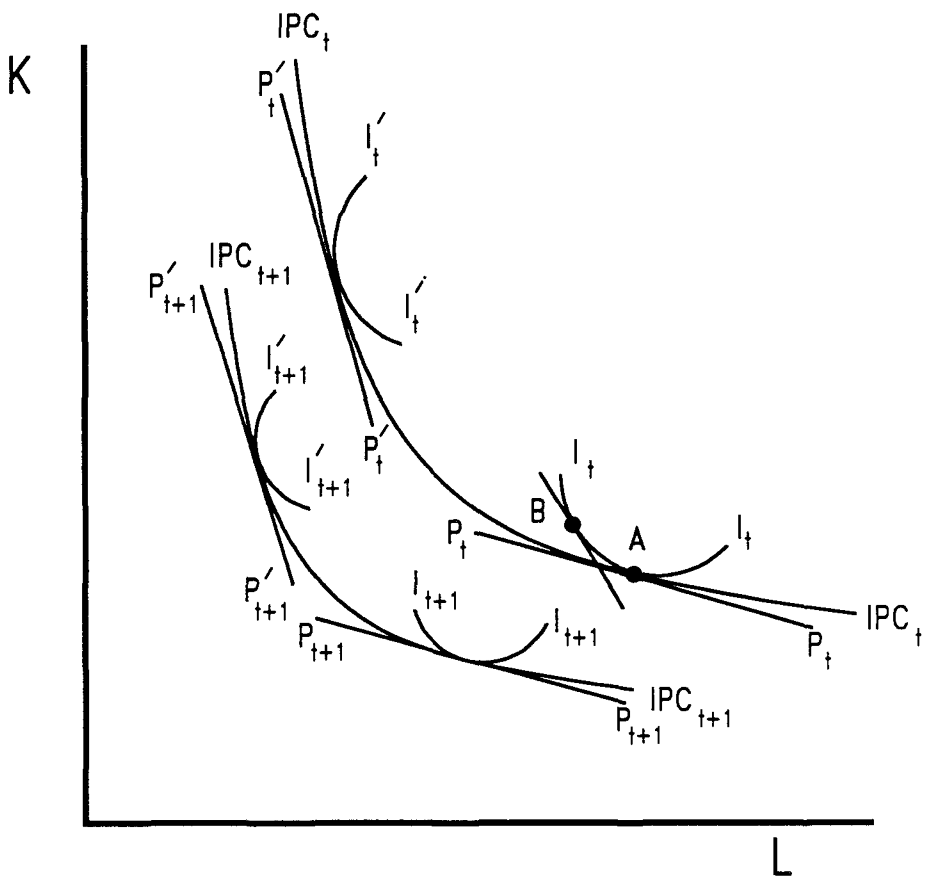
> Since the shape and position of the IPF are not really accounted for by the theory of induced innovation, its application here has succeeded only in taking an old, familiar historical problem and restating it in new, more precise, and considerably more esoteric terms. (David, 1975, p.52).

In criticising Kennedy's IPF, Ahmad (1966) developed a more traditional model of induced innovation consistent with Hicks' original propositions and which does not depend on expectations of future relative factor prices as does Fellner's (1961) model. Ahmad begins by defining an innovation possibility curve (IPC) which at any one time describes the set of technological possibilities open to the firm. Each process in this set is characterised by an isoquant with a relatively small elasticity of substitution (this limits substitution possibilities with any chosen technique). The IPC is the envelope of all unit isoquants, each of which demands a given amount of resources be expended on its development. According to Ahmad (1966, p.347), the IPC thus conceived "...is a purely technological or laboratory question." Economic criteria only enter the firm's decision calculus when a particular isoquant is chosen from the IPC. Azhar (1980) is correct in noting that Ahmad's IPC is defined precisely in the manner Salter (1960) defines his isoquants, and that this is in large part responsible for the opposing conclusions reached by Salter and Ahmad on the possibility of price induced bias in innovation.

Ahmad's model of induced innovation is presented in Figure 6.2. At time t, technological possibilities are defined by IPC_t. Given factor prices P_tP_t, the firm chooses the technology represented by isoquant I_tI_t which minimises costs. Once a technology has been chosen by a firm in a given time period, its technological flexibility (costless substitution possibilities) is limited to the particular isoquant chosen. Ahmad assumes that the cost of moving from one isoquant to another isoquant on the same IPC is the same as that for moving from the original isoquant to another which is on a superior IPC. Thus, once a particular isoquant has been chosen at time t, the remainder of IPC_t is irrelevant to the firm, for a move to a cost efficient point on IPC_{t+1} will always be superior (allow production of a given quantity of output at lower cost) to any point on IPC_t. It is assumed that IPCs move neutrally and that such moves are independent of factor prices. It is possible however, that the IPCs could exhibit a factor-saving bias through time and that this bias could arise even if factor prices remained constant.

If during period t factor prices change to $P'_tP'_t$, then in the short run, the best the firm can do is to move along isoquant I_tI_t from point A to point B. At time t+1, the set of technological possibilities is represented by IPC_{t+1}. With factor prices $P'_{t+1}P'_{t+1}$, the most efficient technology is given by isoquant $I'_{t+1}I'_{t+1}$. Isoquant $I'_{t+1}I'_{t+1}$

FIGURE 6.2: AHMAD'S INNOVATION POSSIBILITY CURVE



Source: Adapted from Ahmad (1966)

uses less labour than I_tI_t or its neutral technical equivalent of period t+1, $I_{t+1}I_{t+1}$, and thus the move from I_tI_t to $I'_{t+1}I'_{t+1}$ constitutes an induced bias in innovation.

Ahmad's model bolsters the arguments of Hicks and provides a more solid microeconomic base for the theory of price induced bias in innovation. Like Kennedy's IPF however, Ahmad's IPC is not precisely defined and the determinants of its form and movement through time are not well developed.

Binswanger (1974) and Binswanger et al. (1978) present perhaps the most sophisticated model of induced innovation. The superiority of this model stems from the explicit attention that is given to the process of research itself. Building on the earlier work of Evenson and Kislev (1971), Binswanger assumes that firms can follow various research paths each directed at reducing the input requirements of specific factors. These research paths have varying costs and expected pay-off functions measured in terms of efficiency improvements. Thus, research is viewed as an investment problem where the aim of the firm is to maximise profits by choosing optimal levels of inputs and research activity.

Binswanger (1974) demonstrates that it is neither factor prices alone, as in Ahmad's (1966) model, nor factor shares alone, as in Kennedy's (1964) model, that drives the rate and direction of technical change. The relative productivity of alternative research paths, changes in the relative costs of capital-saving and labour-saving research and the specification of the research budget are all shown to exert important influences on the characteristics of innovation. Most importantly perhaps, by showing that research is a resource using activity, Binswanger is able to refute Salter's (1960) criticism of Hicks' (1932) induced innovation hypothesis.

A common criticism of much of the above work is the representation of technological progress by shifts in entire production functions. Atkinson and Stiglitz (1969) correctly point out that the continuous production function is comprised of a number of distinct production techniques and that a change in one of these techniques does not necessarily affect any others. Thus, technological change should be represented by the outward movement of the production function at a given point. This argument recognises the local nature of much technological development and is closely related to Arrow's (1962) learning by doing model. Arrow's model and the subsequent work on localised learning, search and innovation by David (1975) are examined next.

Arrow's (1962) major contribution to the theory of technical change and innovation is his concept of learning by doing which seeks to endogenise the growth of technical possibilities that underlie shifts of the production function. Borrowing from psychology literature, Arrow's essential premise is that learning, the acquisition of knowledge, is the product of experience which itself is not simply a function of time but rather of experience gained through practice (1962, pp. 155-156). In the arena of production therefore, new technical possibilities emerge as firms gather manufacturing experience working with established techniques.

The model of technical progress developed by Arrow assumes that technical change takes place in the capital goods sector and that new production possibilities introduced to the economy are wholly embodied in new capital goods. All capital goods are assumed to have the same lifetime and depreciation follows a one-hoss shay pattern. The index of experience adopted by Arrow is cumulative gross investment. Utilising a fixed coefficients production function, the fundamental arguments of Arrow's model are:

$$x = \int_{G'}^{G} \gamma(G)dG \ :$$

$$L = \int_{G'}^{G} \lambda(G)dG :$$

where x represents output:

L represents total employment:

$\gamma(G)$ denotes the output capacity of capital goods of vintage G:

$\lambda(G)$ denotes the labour associated with capital goods of vintage G:

G' denotes the capital goods of oldest vintage used in the current period.

Arrow assumes that the capital-output ratio of all capital goods is constant, $\gamma(G) = a$, but that $\lambda(G)$ is a decreasing function of G. More specifically:

$$\lambda(G) = bG^{-n}, \text{ where } n>0,$$

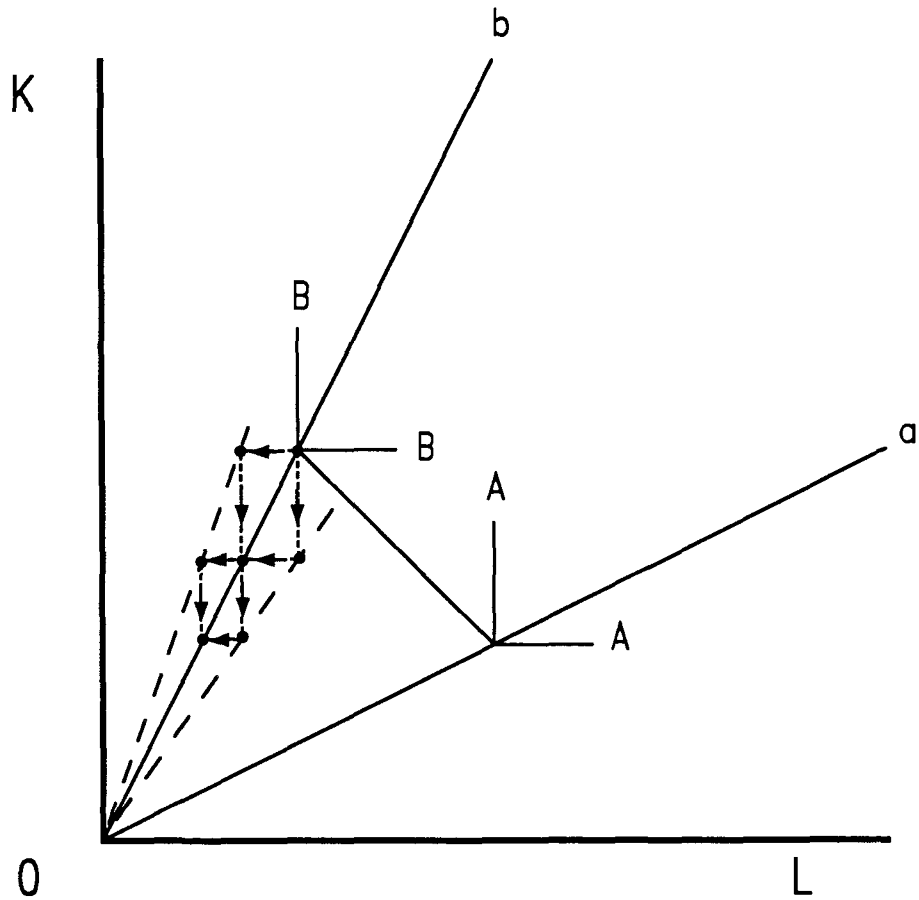
and thus the efficiency of labour is an increasing function of cumulative gross investment given that the capital-output ratio is constant. This form of learning function adopted by Arrow is not purely an ad hoc choice but was based upon empirical evidence from airframe construction.

Though providing an important formal mechanism for technical improvement, Arrow's model had several shortcomings. Firstly, he ignored qualitative improvements in labour inputs themselves. Secondly, the learning by doing model does not allow for efficiency improvements in machinery once installed. That is, learning is confined to the production of capital goods and no learning occurs in the use of a capital good once built. (Arrow acknowledges these two criticisms.) Thirdly, Hacche (1979, p.147) questions the description of the learning process as a description of how technical change occurs. He argues that it is not true that technical knowledge keeps step with experience in the regular manner suggested by Arrow, and that the history of technical progress appears to be more irregular, with rapid advances at discrete moments. Fourthly, Arrow ignores the process of research and development. Atkinson and Stiglitz (1969) note the importance of localised research activity in conjunction with production experience.

David (1975) outlines a model of technical change based upon local search for new techniques. Like Nelson and Winter (1982), he views technological progress as improving production efficiency in limited discrete areas and thus follows Atkinson and Stiglitz (1969) in arguing against the representation of technological change as wholesale movements of the production function.

David (1975) adopts a probabilistic search model in which new production possibilities are always more efficient and thus adopted, thereby bypassing the need to posit an explicit viability (cost reducing) criterion for adoption such as that favoured by Nelson and Winter (1982). Figure 6.3 shows the general logic of David's model. Technical choice is initiated by the myopic consideration of a number of production possibilities; points A and B in this case. The initial choice of technique is assumed to be determined by relative factor prices. Once a particular "basic" technology is chosen however, relative factor prices essentially disappear from the model. Future production possibilities are constrained to lie in a convex cone centred on a path of "neutral" technical progress towards the origin along the chosen process ray. The local search process for David takes the form of a random walk in this convex space defined by proportional reductions in either the capital

FIGURE 6.3: DAVID'S LOCAL SEARCH RAY



Source: Adapted from David (1975)

input coefficient or the labour input coefficient.

For David (1975), technological change is evolutionary in the sense that the initial choice of technique determines the future path of learning. He argues that only in rare cases will a firm move from a particular process ray, because all others will likely be technologically inferior.

David's (1975) work is a useful extension of Arrow's (1962) learning by doing hypothesis, showing, albeit in a limited way, how relative factor prices in a "learning model" can influence the trajectory of technological progress. It also recognises the inability of firms to instantaneously and costlessly substitute factor inputs as relative prices change.

The model is not without its shortcomings however. Firstly, it oversimplifies the variety of different types of possible technical changes, assuming that they are either purely capital-saving or purely labour-saving. In reality, even the class of viable technical changes is much broader than this. Secondly, David is wrong to ignore the importance of relative factor prices after a particular technology has been chosen. Whether relative factor prices remain constant or change, is likely to guide even the path of localised learning. David's model is too rigid, for persistent increases in the relative price of one of the inputs is likely to bias the path of technological progress well away from an individual process ray. Thirdly, David does not make clear the conditions under which firms may move from one process ray to another. This would seem to be an interesting topic demanding further inquiry.

6.2.1 Summary

Through the work of Hicks (1932), the neoclassical school has provided the most thorough exposition of price induced bias in innovation. Binswanger (1974) provides more solid footing for the induced innovation hypothesis, countering Salter's (1960) criticism of Hicks' thesis. The strict neoclassical model with its continuous production function has many problems however. Firstly, the separation of factor substitution from technical change is more of a theoretical convenience than a representation of a real distinction in the process of production. It is not at all clear what, if any, factor substitution possibilities firms enjoy, and it is very doubtful that firms can effortlessly move between such possibilities. Factor substitution should be regarded as one form of technical change, involving adjustments costs and set-up time as any other. Secondly, learning by doing and local search behaviour do not sit very well with the neoclassical representation of technological progress as discrete shifts in entire production functions (Atkinson and Stiglitz, 1969).

David (1975) overcomes some of the failings of the neoclassical model. Adopting a fixed coefficients production function, he attempts to incorporate notions of learning by doing with localised search for new techniques of production. In doing so however, he all but severs the relationship between relative factor prices and the direction of technical change. Nelson and Winter (1982) reintroduce prices in a similar model but only in the form of a viability criterion for the adoption of new techniques. The aim of the next section is to outline a model of localised search which incorporates the influence of relative factor prices to explain the direction of technical change.

6.3 Technical Change

This section provides a working definition of "technical change" that is consistent with earlier arguments in the thesis and that is amenable to measurement. A model is then outlined which shows how relative factor prices influence the direction of technical change.

The section ends with a brief discussion of the effects of technical changes on relative factor prices.

6.3.1 Defining Technical Change

The definition of the technology of a firm (or an industry) follows that provided in the discussion of commodity prices and values in Chapter 3. Assume that in a given production period an individual firm k produces a certain quantity, x_j^k, of an homogeneous commodity j, with inputs of capital and labour. While labour inputs are assumed to be of a uniform type, capital inputs are of two distinct sorts. The first type of capital inputs are circulating constant capital goods. These are material inputs and energy inputs and are distinguished by the fact that their entire value is given up to production in any one period. The second type of capital inputs are fixed constant capital goods. These inputs have a service life of several turnover periods and give up their value only slowly in production.

The total amount of labour used by a firm k in a given period is l^{+k}. The unit labour requirements associated with output x_j in firm k is therefore $l^{+k}/x_j^k = l_j^k$. Similarly, the unit requirements of circulating capital inputs i required in the production of output x_j in firm k is given by the vector $\mathbf{a}_j^k = (a_1^k, a_2^k, \ldots, a_n^k) = (a_1^{+k}, a_2^{+k}, \ldots, a_n^{+k})/x_j^k$. (Again, the addition symbol denotes the total amount of an input used in a production period.) Lastly, the fixed capital required to produce output x_j in firm k in a given turnover period is denoted by the non-negative vector $\mathbf{f}_j^k = (f_1^k, f_2^k, \ldots, f_n^k) = (f_1^{+k}, f_2^{+k}, \ldots, f_n^{+k})/x_j^k$. Each type of fixed capital input is assumed to have a specific service life.

The technology employed by firm k at a specific moment in time may thus be characterised by the vector $\mathbf{v}_j^k = (l_j^k \mathbf{a}_j^k \mathbf{f}_j^k)$. To simplify the following arguments, it is assumed that all capital goods may be aggregated together and techniques described by a vector of an aggregate capital coefficient and a labour coefficient $\mathbf{v}_j^k = (l_j^k a_j^k)$. This simplification is consistent with the two commodity economy discussed in Chapters 4 and 5. The detailed arguments above are provided for clarification. Technical change is then defined as any alteration in the coefficients of the technology vector such that $\mathbf{v}_j^{k*} \neq \mathbf{v}_j^k$, where the * indicates the new technique of production. In the remainder of this chapter, the subscripts and superscripts are dropped from the notation, the arguments applying to all firms in the economy.

Technological change so defined captures a variety of different types of production reorganisation: changes in the scale of production, changes in the speed of production (here captured through measures of fixed capital), changes in the capacity utilisation rate, substitution between inputs and the adoption of new production techniques either copied from other firms or stemming from in-house research and development. While the contribution of most of these production alterations to measures of performance are examined individually in Chapter 7, the task here is more limited, simply to show how relative factor prices influence the direction of technical change.

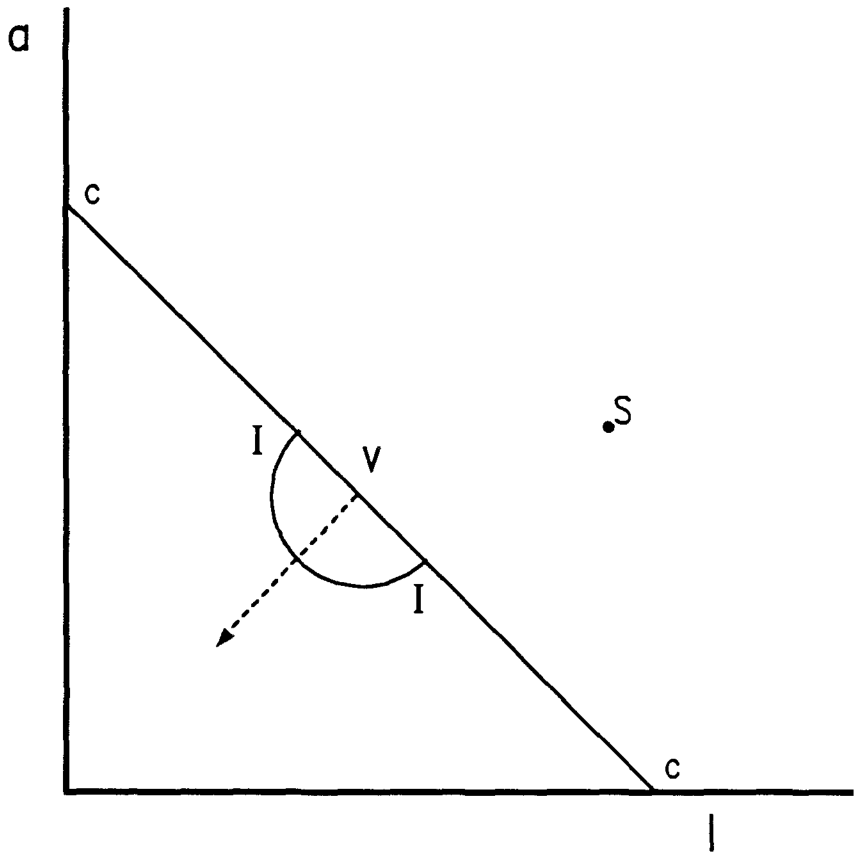
6.3.2 The Likely Direction of Technical Change

In the simplified two input case, the technique of production for the firm can be represented in a diagram such as Figure 6.4. The axes in Figure 6.4 denote the aggregate capital and labour inputs required to produce a unit of output of the given commodity. In this figure the positive orthant maps an input space and the technique adopted by a firm at a given time can be represented by some point such as **v**. The production technology is therefore assumed to be fixed each turnover period. Factor substitution constitutes technical change in this model. This conceptualisation of technology is not inconsistent with "putty-clay" models (see Solow, 1960 and Johansen, 1959). While some technical change is possible between turnover periods, as variable factors of production are changed, the basic form of technology is constrained by the characteristics of the fixed capital in place, and drastic alterations in technology demand the replacement of fixed capital. There is no technical change within a production period. Thus it is assumed that experience garnered in production is stored and affects technological choices only in subsequent rounds of production. This learning may affect the quality of both capital and labour inputs.

Technical change is represented in Figure 6.4 by a move of the firm in this technology or input space away from point **v**. The firm will move when a new technology has been located. This may result from direct research activity on the part of the firm, from the selection of known but untried techniques or from copying the actions of competitors or even firms in different markets.

The essential argument of David (1975), Binswanger et al. (1978)

FIGURE 6.4: THE LIKELY DIRECTION OF TECHNICAL CHANGE



and Nelson and Winter (1982), is that firms search locally for new techniques and therefore that the likelihood of a new technique being adopted is inversely proportional to its distance from the existing technology. This argument is adopted in this model. It seems reasonable to suppose that our representative firm will examine all techniques in the vicinity of **v** more carefully than those around any other point in the input space. Techniques around some other point such as **s** will not be examined for the firm has little idea of production possibilities near **s**. Firms acquire knowledge in production and thus the existing technology anchors and influences the search process. In this sense, the search for new techniques is localised. In another sense too, search is localised in this model. While the search process perhaps uncovers a number of superior techniques, these do not imply a wholesale shift in production technology, merely the advancement of technical knowledge in discrete areas (after Atkinson and Stiglitz, 1969), particularly in those areas around the new technologies chosen. Thus, the path of future technical change is seen to be dependent on past technical choices.

The adoption of a new technique depends primarily on economic criteria. In Chapter 5 it was argued that firms in a competitive market will only adopt a new technique of production if it lowers unit costs at prevailing market (expected) prices, that is if

$$pa^* + wl^* < pa + wl :$$

where p represents the unit cost of the aggregate capital input:

w represents the unit cost of labour.

In this example, the firm will have knowledge of production possibilities in the vicinity of **v**. The isocost line cc divides these production possibilities into a set of cost-increasing techniques, those that lie above the isocost line, and a set of cost-reducing techniques, those that lie below the isocost line. The only techniques that a competitive firm will consider adopting are those that fall into the latter category. No rational firm with appropriate knowledge will move to an inferior (cost increasing) technology, for this would decrease its profits at existing market prices. This is not to say that firms do not make wrong choices, rather that in general, the continuation of the capitalist mode of production demands that on average most firms do make the correct choices. Thus, the techniques that are candidates for adoption are those that lie below the isocost line cc. It is important to realise that changes in relative factor prices will change the slope of the isocost line (-w/p) and thus alter the set of viable technical changes associated with each point in the input space.

The factor price ratio affects the choice of technique in a more fundamental way however. It is assumed here that firms will adopt any new technique that lowers costs at existing prices. That is, firms are not disposed to adopting labour-saving technical changes over capital-saving ones, all are equally likely to be adopted if they are viable. Further, the model outlined here explicitly rejects the argument that labour-saving technical changes will occur more frequently than capital-saving ones as capitalists attempt to reduce their dependence especially on labour. In Figure 6.4, the isoline II traces a 180 degree arc that maps the continuum of possible research directions. This symmetric probability distribution is used to find the expected direction of technical change for any competitive firm producing with technology **v** and facing relative factor prices denoted by the slope of the isocost line cc. The most likely, or expected, direction of technical change $E(\theta)$ can be determined up to a probability distribution in the following manner.

$$E(\theta) = \int_0^{\pi} \theta \Pr(\theta) d\theta \qquad (6.3)$$

$$= \int_0^{\pi/2} \theta \Pr(\theta) d\theta + \int_{\pi/2}^{\pi} \theta \Pr(\theta) d\theta : \qquad (6.4)$$

where the integral is evaluated between 0 and π radians (0-180 degrees).

Assuming that the probability distribution is unimodal and symmetric,

$$Pr(\theta) = Pr(\pi-\theta) = Pr(\phi) ,$$

and equation 6.4 can be rewritten as

$$E(\theta) = \int_0^{\pi/2} \theta Pr(\theta)d\theta + \int_0^{\pi/2} (\pi-\phi)Pr(\phi)d\phi$$

$$= \int_0^{\pi/2} \theta Pr(\theta)d\theta + \pi\int_0^{\pi/2} Pr(\phi)d\phi - \int_0^{\pi/2} \phi Pr(\phi)d\phi$$

$$= \pi\int_0^{\pi/2} Pr(\phi)d\phi$$

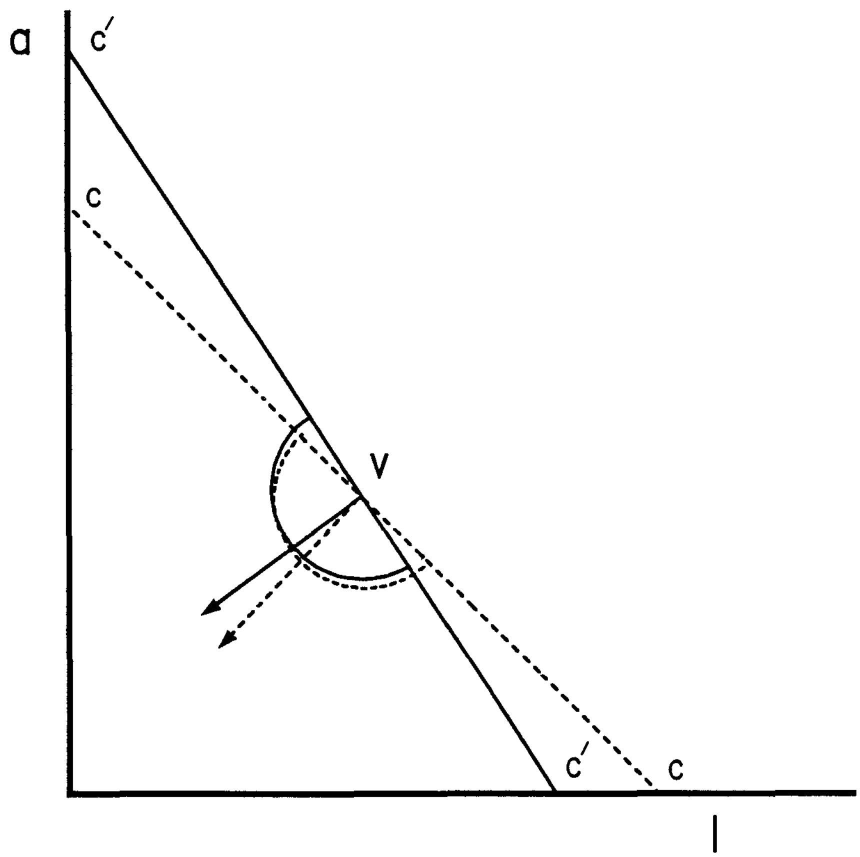
$$= \pi/2 = 90^o. \tag{6.5}$$

Thus, the likely direction of technical change is orthogonal to the isocost line, shown by the arrow in Figure 6.4. The expected direction of technical change in this model is therefore determined by relative factor prices, following the arguments of induced innovation theory.

The effects of changes in relative factor prices on the likely direction of technical change are shown in Figure 6.5. The original factor price ratio cc, is drawn such that the relative prices of the two inputs are the same. In this case, the likely direction of technical change is neutral. From **v** the most likely path of technological progress is down a ray towards the origin. The model behaves intuitively correctly. In this example, there is no reason why technical change should exhibit a capital-saving or labour-saving bias.

Now assume that the price of a unit of labour increases relative to the price of a unit of capital. Thus, the new isocost line c'c' will

FIGURE 6.5: THE EFFECT OF AN INCREASE IN THE RELATIVE PRICE OF LABOUR ON THE LIKELY DIRECTION OF TECHNICAL CHANGE



be steeper than the old one. Once more, the isocost line divides the input space into a set of cost-increasing techniques and a set of cost-reducing techniques. However, these respective sets are not equal to those defined by the original isocost line. The new cost-reducing set includes a greater number of techniques that use relatively less labour and more capital than the original cost-reducing set. With more relatively labour-saving technologies in the set of viable new techniques, the likely direction of technical change is biased towards saving labour. This result is also intuitively correct. If the price of labour increases relative to that of capital one might expect that the direction of technical change will exhibit a labour-saving bias. Figure 6.5 shows the labour-saving bias of technical change in this example. It is also easy to see how the degree of bias in innovation is influenced by the factor price ratio. If labour becomes even more expensive relative to capital, the slope of the isocost line will become steeper still and the orthogonal to the isocost line, mapping the likely direction of technical change, will show a greater labour-saving bias. The model performs equally well in the case of increases in the relative price of capital.

Unlike David's (1975) model, the one developed here does not arbitrarily assume that technical change will be neutral. Only if the slope of the isocost line is equal to the negative reciprocal of the capital-labour ratio, will the direction of technical change be neutral in the sense of preserving the capital-labour ratio. Neutral technological change would therefore only occur by accident.

The path of technological progress is determined by movements of the relative factor price ratio over time. It is possible then that continued innovation may lead a firm to occupy a position on one of the axes, or even on the origin. It is assumed however that firms must use at least some of both inputs in production. Thus, a mechanism is required to keep the firm from moving to a position on one of the axes. Binswanger et al. (1978) provide a potential solution to this problem. They recognise that the pace of technical change depends in part on the technology presently adopted by a firm. A firm producing with relatively large capital and labour inputs for example would probably be able to reduce those inputs by a larger amount for a given research expenditure than a firm producing with a more efficient technique. Thus, Binswanger et al. (1978) show that if research expenditures remain constant it is more likely that input coefficients will be reduced by a constant proportion rather than by a constant absolute amount. David (1975) uses this same argument to establish the neutrality of technical change in his model and to prevent firms from reaching a production point on one of the axes. This argument is also adopted here.

There is an additional reason to suspect that firms will not reach one of the axes in the probabilistic model developed in this chapter. As firms approach the axes bounding the input space and if they are not using a technique characterised by a capital-labour ratio of unity, then the distribution of viable new techniques tends to be skewed away from the nearest axis. While it is unclear what the precise direction of technical change will be in this case, it is clear that it will be "pushed" away from the closest axis.

In summary, the model of the likely direction of technical change outlined here seems to offer various advantages over the standard neoclassical model and the model of David (1975). Firstly, it incorporates some notion of learning by doing and especially local search behaviour and thus addresses the concerns of Atkinson and Stiglitz (1969). Secondly, it shows explicitly how the direction of technical change is influenced by relative factor prices and thus overcomes the random course of technical change in David's model.

6.3.3 Accumulation and Relative Factor Prices

In Chapter 5 it was shown that under certain conditions labour-saving technical change can reduce the rate of profit. In the last section of this chapter, the bias of innovation was explained by changes in relative factor prices. In the simple two department model where there are only two inputs to production, can we say anything about the movement of relative factor prices?

The factor price ratio is (λ_1/λ_L), where $\lambda_L = \lambda_2 D$. From Chapters 3 and 5, the values of the capital and consumer goods are determined by techniques of production. The value of labour-power however also varies with the real wage which in turn is assumed to be a positive function of the employment rate. Assuming that there is no technical change, so that $d\lambda_j = 0$, for j=1,2, the relative price of capital to labour will increase as the real wage falls and it will decrease as the real wage rises. Thus, if the economy is expanding faster than the supply of labour, real wages will be bid up and the price of labour relative to capital will rise.

With technical change the picture is complicated a great deal. To simplify the analysis recourse is made to the assumptions of Chapter 5. Thus, the effects of technical change on the relative prices of capital and labour are examined between equilibrium positions characterised by differences in techniques of production. The effects of technical change on the expected prices of capital and consumer goods are shown in Chapter 5. From Appendix 2, reductions in capital and labour input coefficients in both departments of production cause the real wage to rise. The effects of technical changes of various sorts on the relative prices of capital and labour can be summarised as follows. Firstly, reductions in the capital or labour input coefficients in department 2 decrease the value of consumer goods, they leave the value of capital goods unaffected and they cause the real wage to rise. The effects of technical change in department 2 on the relative price of capital and labour ($\lambda_1/\lambda_2 D$) is thus ambiguous. Secondly, reductions in the capital or labour input coefficients in department 1 cause the value of capital and consumer goods to fall, but the value of capital goods falls faster than the value of consumer goods, and these technical changes also cause the real wage to rise. Thus, technical changes in department 1 cause the price of labour relative to capital to increase.

In summary, it is unclear how the relative prices of capital and labour will vary because of technical changes. Labour-saving technical change in the simple model of Chapter 5 does not reduce the demand for labour and thus real wages will increase as the economy expands faster than the labour force even allowing for the effects of technical change. If technical changes occur with greater regularity in department 2 however, the value of consumer goods will be reduced and it is unclear how the value of labour-power will be affected. Relative factor prices will vary depending on the size of the two departments of production, the pace of technical change in each department and the rate of growth of the economy relative to the rate of growth of the labour force.

6.4 The Direction of Technical Change and Relative Factor Prices in the Canadian Food and Beverage Industry

In this section, regression techniques are employed to examine the relationship between the bias of technical change and relative factor prices. While several other independent variables may enter the regression model, the analysis here is not a general examination of the determinants of technical change. It is recognised, following Mansfield (1968), Rosenberg (1976) and more recently, Binswanger et al. (1978), that market structure, size and other characteristics of firms and their environment influence patterns of research, development and innovation.

Data for the Canadian food and beverage industry is used to examine the induced innovation hypothesis. This data is disaggregated by region (see Chapter 7) and spans the period 1961 to 1984. A more complete discussion of the data set, its characteristics and limitations, are provided in the following chapter and in Appendix 3. Appendix 3 also provides a detailed description of how the variables used in this analysis were measured.

The technique of production in this section is measured in three ways. All measures are derived from the technical composition of capital introduced in Chapter 3. The technical composition of capital is defined as the ratio of the physical amount of capital employed in production to the physical amount of labour employed. It is measured as

$$P = K/Lt' : \qquad (6.6)$$

where K is the physical quantity of capital inputs to production (fixed and circulating):

L is the physical quantity of labour used in production:

t' is the length of the turnover period.

Removing the effects of changes in the speed of production, equation (6.6) can be rewritten as

$$= \frac{1}{t'} \left[\frac{1}{R} \frac{K_u}{L} + \frac{K_c}{L} \right] :$$

where R is the rate of capacity utilisation:

K_u/L is the full capacity ratio of fixed capital to labour:

K_c/L is the cost of fuel and raw materials processed per hour of labour.

Three measures of technical change form the dependent variables in the following analyses. The first of these measures is the technical composition of capital adjusted for variations in the length of the turnover period (K/L). This variable provides a general indicator of the technology of an industry and is equivalent to the ratio of capital and labour input coefficients, except that the capital measure represents the capital cost of producing a unit of output. The adjustment for variations in the length of the turnover period removes the influence of market characteristics, reflected by changes in levels of owned inventories per unit output, that otherwise shroud the measure of technology. The second measure is the capacity adjusted fixed capital to labour ratio (K_u/L). This variable provides a direct indication of the process of mechanisation in production. The third measure of technical change is the cost of fuel and raw materials processed per hour of labour and this provides an indication of the intensity of the labour process (K_c/L).

The dependent variables are regressed in turn on three independent variables. The first of these is real output. As real output increases, it is reasonable to suspect that firms are adding to their inputs of both capital and labour. New capital by and large tends to be more productive than old capital and thus any additions to the capital stock will likely alter the ratio of capital to labour employed and thus the technique of production. Changes in the capital stock would serve the same purpose as the level of output in the regression model. Severe problems of multi-collinearity force one of these measures to be dropped however. As the level of the capital stock is so closely related to two of the indicators of technical change this variable was omitted from the subsequent analysis.

The second independent variable included in the regression model was the deflated value of the annual surplus or profit. It is hypothesised that as profit increases so firms may have larger retained earnings which they might invest in additional inputs. Greater profits are thus seen as an inducement to further investment. The rate of profit was not incorporated in the regression model. It is not clear what effect the rate of profit would have on investment and therby technical change. On the one hand, higher rates of profit may be a positive inducement to expand production as firms invest in the hopes of continued high returns. On the other hand, increases in the rate of profit may be associated with increases in the rate of interest and the price of capital. An increase in the price of capital is a disincentive to investment. Again however, collinearity among independent variables forced the removal of this term. In addition, problems of circularity between the rate of profit and the dependent variables, made identification of any causality particularly problematic.

The third independent variable in the regression models is the ratio of the expected price of capital to the expected price of labour. This variable is included to test the central hypothesis of induced innovation theory. It is expected that an increase in the relative price of either capital or labour will encourage firms to adopt new techniques of production that save on the relatively more expensive factor.

A number of alternative specifications of the regression model were tried, including lagging the independent variables by up to three periods. While the relatively simple model presented here does not maximise the explained variation in the dependent variable, nor does it maximise the significance of all the independent variables, it does have the advantage of yielding results which are relatively straightforward to interpret.

An immediate problem encountered in the regression analysis was serial correlation among the error terms. In the original runs of the estimation, the Durbin-Watson statisitic was significantly less than one in all regions across all three dependent variables. To remove this problem, first differences of all variables were obtained and the coefficients of the regression models re-estimated. First differencing the data also significantly reduced problems of collinearity among the independent variables. The regression models were estimated with no intercept term for with first differences inclusion of an intercept may bias the estimates of the remaining parameters (Koutsoyiannis, 1977). The results of the analysis are presented in Tables 6.1-6.3 and are discussed briefly below.

Table 6.1 shows the results of regressing the technical composition of capital adjusted for variations in the speed of production against the three independent variables, real output, real profits and the expected factor price ratio. The most encouraging result from this model is the general significance of the factor price ratio in accounting for the variation in this first measure of technology. In all regions, except Alberta, increases in the relative price of labour are significantly associated with technical changes that save on the increasingly expensive input. In Alberta too, the sign on the price ratio variable was consistent with the other regions and the induced innovation hypothesis, though the estimated parameter in this case was not significantly different from zero. In general, increases in the level of output are associated with increases in the capital-labour ratio. Output exerted a significant positive influence on the dependent variable in the food and beverage industry in Quebec, Ontario and Canada. In the Prairies and Alberta, the relationship between output and the technical composition of capital adjusted for the length of the turnover period was positive, but in the Atlantic region and BC this relationship was negative. In these latter four regions, the estimated parameter on the independent variable was not significantly different from zero at the given probability levels. While the influence of output and relative prices on the direction of technical change was largely as anticipated, the same cannot be said for the influence of the level of profits on the bias of innovation. Only in BC did the level of profits exert a positive impact on the capital-labour ratio. In all other regions, this relationship was negative, though only significant in Quebec. In general, first differencing the data significantly reduced the

TABLE 6.1: EXAMINING THE DETERMINANTS OF TECHNICAL CHANGE IN THE CANADIAN FOOD AND BEVERAGE INDUSTRY: THE TECHNICAL COMPOSITION OF CAPITAL ADJUSTED FOR THE LENGTH OF THE TURNOVER PERIOD

CANADA	$Y = 0.0005(Q)^{*} - 0.0013(P) - 24.9(\lambda_1/\lambda_L)^{*}$		$R^2 = 45.1\%$
	$(2.1) \quad (-0.9) \quad (-2.8)$		$DW = 1.4$
ATLANTIC	$Y = -0.0028(Q) - 0.0112(P) - 22.4(\lambda_1/\lambda_L)^{*}$		$R^2 = 24.4\%$
	$(-0.67) \quad (-1.42) \quad (-2.85)$		$DW = 1.6$
QUEBEC	$Y = 0.0026(Q)^{**} - 0.0117(P)^{**} - 16.4(\lambda_1/\lambda_L)^{*}$		$R^2 = 50.1\%$
	$(2.99) \quad (-3.16) \quad (-2.19)$		$DW = 1.6$
ONTARIO	$Y = 0.0148(Q)^{**} - 0.005(P) - 36.9(\lambda_1/\lambda_L)^{**}$		$R^2 = 62\%$
	$(3.06) \quad (-1.99) \quad (-4.72)$		$DW = 1.3$
PRAIRIES	$Y = 0.0045(Q) - 0.0097(P) - 21.0(\lambda_1/\lambda_L)^{*}$		$R^2 = 24\%$
	$(1.48) \quad (-0.61) \quad (-2.17)$		$DW = 1.4$
ALBERTA	$Y = 0.0052(Q) - 0.0019(P) - 14.6(\lambda_1/\lambda_L)$		$R^2 = 15\%$
	$(1.5) \quad (-0.13) \quad (-0.85)$		$DW = 0.8$
BC	$Y = -0.0052(Q) + 0.0263(P)^{*} - 43.5(\lambda_1/\lambda_L)^{**}$		$R^2 = 40.6\%$
	$(-1.66) \quad (2.32) \quad (-3.26)$		$DW = 1.8$

where Y = K/L, the technical composition of capital adjusted for changes in the speed of production:

Q = real output:

P = real profits:

λ_1/λ_L = the unit price of capital relative to that of labour:

DW denotes the Durbin-Watson statistic:

t-scores are shown in parentheses:

* denotes significant in a two-tailed test at the 0.05 probability level:

** denotes significant in a two-tailed test at the 0.01 probability level:

n is 24 and there are 20 degrees of freedom.

explanatory power of the independent variables in the regression models. It did however, reduce the problems of serial correlation in all regions except Alberta.

Table 6.2 presents a regression model of identical form to that just discussed, though the dependent variable in this case is the capacity adjusted fixed capital to labour ratio. This measure perhaps better than others captures the technological choices made by the firm, for fixed capital embodies distinct technologies that in large part control the flow of all other inputs to the sphere of production. The relative factor price ratio in all regions except Alberta, exhibits the anticipated negative sign, though only in Ontario is the estimated parameter significantly different from zero. In this regression model, the influence of output is the most significant determinant of the fixed capital-labour ratio. In all regions, output is positively associated with the dependent variable and this influence is significant in 6 of 7 regions. Again, the influence of profits on the dependent variable is ambiguous. The given form of the regression model on the whole performs better in predicting the fixed capital-labour ratio than the general capital-labour ratio, with a coefficient of determination in this case exceeding 60% in most regions. Serial correlation was again a problem in Alberta.

Table 6.3 presents the results of the third regression model, examining the influence of the three independent variables on the intensity of the labour process, measured by the amount of fuel and materials processed per hour of labour. The results for this model are almost identical to those presented in Table 6.2, with output exerting

TABLE 6.2: EXAMINING THE DETERMINANTS OF TECHNICAL CHANGE IN THE CANADIAN FOOD AND BEVERAGE INDUSTRY: THE CAPACITY ADJUSTED FIXED CAPITAL TO LABOUR RATIO

CANADA	Y =	$0.0008(Q)^{**} + 0.0801(P) - 5.02(\lambda_1/\lambda_L)$ (7.04) (0.14) (-1.14)	$R^2 = 80.2\%$ DW = 1.2
ATLANTIC	Y =	$0.0014(Q) - 0.0031(P) - 6.79(\lambda_1/\lambda_L)$ (0.76) (-0.87) (-1.89)	$R^2 = 18.8\%$ DW = 1.8
QUEBEC	Y =	$0.0037(Q)^{**} - 0.006(P)^{*} - 4.15(\lambda_1/\lambda_L)$ (7.05) (-2.7) (-0.93)	$R^2 = 76.7\%$ DW = 1.3
ONTARIO	Y =	$0.0023(Q)^{**} - 0.0002(P) - 12.9(\lambda_1/\lambda_L)^{**}$ (8.51) (-0.14) (-3.01)	$R^2 = 85.1\%$ DW = 2.1
PRAIRIES	Y =	$0.0111(Q)^{**} + 0.0004(P) - 5.57(\lambda_1/\lambda_L)$ (6.82) (0.04) (-1.08)	$R^2 = 78.5\%$ DW = 2.1
ALBERTA	Y =	$0.0095(Q)^{**} - 0.0055(P) + 5.15(\lambda_1/\lambda_L)$ (5.56) (-0.75) (0.61)	$R^2 = 69.5\%$ DW = 0.9
BC	Y =	$0.0054(Q)^{**} + 0.0213(P)^{**} - 9.13(\lambda_1/\lambda_L)$ (3.56) (4.4) (-1.43)	$R^2 = 62.7\%$ DW = 2.0

where Y = K_u/L, the capacity adjusted fixed capital to labour ratio:

Q = real output:
P = real profits:
λ_1/λ_L = the unit price of capital relative to that of labour:

DW denotes the Durbin-Watson statistic:
t-scores are shown in parentheses:
* denotes significant in a two-tailed test at the 0.05 probability level:
** denotes significant in a two-tailed test at the 0.01 probability level:
n is 24 and there are 20 degrees of freedom.

TABLE 6.3: EXAMINING THE DETERMINANTS OF TECHNICAL CHANGE IN THE CANADIAN FOOD AND BEVERAGE INDUSTRY: THE AMOUNT OF FUEL AND MATERIALS PROCESSED PER HOUR OF LABOUR

CANADA	$Y =$	$0.0026(Q)^{**} - 0.0031(P) - 3.8(\lambda_1/\lambda_L)$ $(9.58) \quad (-1.85) \quad (-0.38)$	$R^2 = 83.8\%$ $DW = 1.1$
ATLANTIC	$Y =$	$0.0072(Q) - 0.0268(P)^{**} - 11.2(\lambda_1/\lambda_L)$ $(1.62) \quad (-3.14) \quad (-1.32)$	$R^2 = 43.4\%$ $DW = 1.8$
QUEBEC	$Y =$	$0.0117(Q)^{**} - 0.0275(P)^{**} - 3.4(\lambda_1/\lambda_L)$ $(9.22) \quad (-5.08) \quad (-0.31)$	$R^2 = 82.7\%$ $DW = 1.4$
ONTARIO	$Y =$	$0.0066(Q)^{**} - 0.0092(P)^{**} - 16.1(\lambda_1/\lambda_L)$ $(12.75) \quad (-3.4) \quad (-1.93)$	$R^2 = 89.2\%$ $DW = 2.2$
PRAIRIES	$Y =$	$0.0414(Q)^{**} - 0.0458(P) - 7.6(\lambda_1/\lambda_L)$ $(8.37) \quad (-1.77) \quad (-0.48)$	$R^2 = 80\%$ $DW = 2.2$
ALBERTA	$Y =$	$0.0487(Q)^{**} - 0.0718(P)^{*} + 31.3(\lambda_1/\lambda_L)$ $(6.43) \quad (-2.23) \quad (0.84)$	$R^2 = 69.6\%$ $DW = 0.9$
BC	$Y =$	$0.0221(Q)^{**} + 0.0091(P) - 9.2(\lambda_1/\lambda_L)$ $(6.21) \quad (0.79) \quad (-0.61)$	$R^2 = 70.7\%$ $DW = 2.0$

where $Y = K_c/L$, the amount of fuel and materials processed per hour of labour:

Q = real output:

P = real profits:

λ_1/λ_L = the unit price of capital relative to that of labour:

DW denotes the Durbin-Watson statistic:

t-scores are shown in parentheses:

* denotes significant in a two-tailed test at the 0.05 probability level:

** denotes significant in a two-tailed test at the 0.01 probability level:

n is 24 and there are 20 degrees of freedom.

the strongest and most consistent effect on the dependent variable. The amount of profit is significantly inversely related to the intensity of the labour process in four regions. Again, the factor price ratio exhibits the anticipated sign in all regions except Alberta, though the parameter estimates are nowhere significantly different from zero. The regression model in general performs best in this case, with the explained variance in the dependent variable exceeding approximately 70% in 6 regions and surpassing 80% in 4 regions.

6.5 Conclusion

This chapter outlines a probabilistic model of the direction of technical change. Factor-saving bias in innovation is shown to depend on movements of relative factor prices. The model is an extension of the arguments of induced innovation theory, incorporating notions of learning by doing and localised search behaviour. The model thus overcomes some of the criticisms of its earlier neoclassical variant.

The theoretical arguments raised are empirically examined using data from the Canadian food and beverage industry disaggregated by region. The empirical analysis supports the central claim of induced innovation theory, for changes in the relative prices of capital and labour inputs are generally associated with technical changes that are biased toward reducing the inputs of the more expensive factor of production. The empirical results also confirm the importance of embodiment arguments with the capital-labour ratio and real output exhibiting a significant positive relationship with technical change. The direction of causality is in question here perhaps, for one may anticipate increases in the capital-labour ratio accompanying changes in the scale of production leading to increased levels of output. The results do not in general support the notion that increased profits induce firms to increase investment.

Chapter 5 showed that labour saving technical changes may cause the aggregate rate of profit in an economy to fall. The present chapter attempted to explain the bias of technical change using the arguments of induced innovation theory. While changes in relative factor prices do indeed seem related to the bias of technical change, the static analysis here goes only a short way in examining the relationship between prices, profits and technical change. Clearly what is needed now is a more thorough examination of the relationship between technical change and commodity prices. While the theoretical demands of this task are beyond the scope of this thesis, the following chapter does contribute to this line of research by an empirical examination of the effects of technical changes on commodity prices and measures of economic performance in the Canadian manufacturing sector.

CHAPTER 7

TECHNICAL CHANGE AND REGIONAL ECONOMIC PERFORMANCE IN CANADIAN MANUFACTURING

7.1 Introduction

The rate of profit in Canadian manufacturing fell from 45.9% in 1955 to 29.1% in 1984. As the rate of profit declined, so the rate of growth of real manufacturing output decreased from an annual average rate of 5.7% between 1955 and 1974 to 0.004% between 1979 and 1984. Manufacturing employment growth in Canada also declined. Between 1955 and 1974 the number of hours worked in manufacturing increased at an annual average rate of 1.3%. From 1979 to 1984 however, the number of hours worked fell by 1.8% per annum. Those workers fortunate to retain their jobs over the latter part of the period have seen the purchasing power of their wages slowly eroded: while real wages rose at an annual average rate of about 3.6% between 1955 and 1974, they fell throughout the late 1970s and by 1984 they were lower than in 1977. As the manufacturing labour force continues to be trimmed, so over much of the post-war period the unemployment of fixed capital has increased, with capacity utilisation rates falling dramatically through the 1970s (Webber and Rigby, 1986). The Canadian manufacturing sector, like that of the United States and many West European nations (see Wolff, 1986; Lipietz, 1986; and Reati, 1986) appears to be in a crisis.

To what extent do these figures belie significant spatial and sectoral variations? Is manufacturing decline widespread, or is it specific to certain industries and regions? While the theoretical arguments of Chapters 5 and 6 provide a logic for understanding the dynamics of competition, technical change and economic crises, they do not assert that all firms, industries and regions will share a common history of development. Although the Canadian manufacturing sector appears to be faltering, it is by no means clear that the economic performance of all industries or all regions is suffering the same crisis of profitability.

The empirical work in this chapter has three aims. The first is to document the post-war performance of the manufacturing sector in several regions of Canada. While researchers in Canadian regional economics can draw upon a rich body of data, there is a surprising lack of comparative studies within the Canadian economy, both at the level of the industry and the region. The second and related aim of this enquiry is to gauge the extent to which the crisis in Canadian manufacturing as a whole reflects the performance of different regions and industries. The third aim is to evaluate the effects of various types of technical change in Canadian manufacturing. The work is guided by the theoretical arguments outlined in Chapters 3-6.

This chapter is organised in 5 parts. Section 2 briefly describes the data and provides a guide to its analysis. The analysis proper is divided into two parts: in Section 3, regional variations in the economic performance of the manufacturing sector as a whole are documented and explained; in Section 4, the performance of the food and beverage industry in the same regions is analysed. Section 5 concludes the chapter summarising the main results.

7.2 Data and Methods

This section outlines the two data sets employed in this chapter, the time-frame of the study and the regional divisions used. A more comprehensive discussion of the data, sources and techniques of measurement may be found in Appendix 3.

7.2.1 Data

Two data sets are employed in the following analysis. The first is an aggregate of all twenty manufacturing sectors identified by Statistics Canada. This data base is used to reveal the fortunes of the manufacturing sector as a whole in six regions between 1955 and 1984. The time series is limited by the availability of regional capital stock information.

It is often argued that regional manufacturing performance is in large part determined by the mix of industries contained in a particular region (Fuchs, 1962 and Rees, 1979). This argument is examined using the second data base which focuses on the food and beverage industry alone. Examining one such industry provides a crude means of adjusting for industry mix differences between regions. It is recognised that this adjustment is not perfect, for the food and beverage sector itself comprises nine sub-sectors (see Appendix 3). The food and beverage sector was chosen for this task largely because of the availability of data: it is the only manufacturing sector for which capital stock figures are readily available on a regional basis. In addition, the food and beverage industry is well represented in all regions, in 1984 ranking no less than fourth out of twenty industries in any region in both the size of its capital stock and its labour force. The data series for the food and beverage sector starts in 1961 rather than 1955, for a reclassification of industries and the definition of certain economic variables in 1961 makes direct comparison with data of earlier years problematic.

Six regions within Canada are examined: Quebec, Ontario, Alberta, British Columbia, the Atlantic region (Newfoundland, Prince Edward Island, New Brunswick and Nova Scotia) and the Prairie region (Manitoba and Saskatchewan). The Atlantic provinces and the Prairie provinces were combined to avoid problems of missing data which are especially acute at the industry level for individual provinces.

7.2.2 Methods

Representing the maximum rate of accumulation and reflecting both the state of the market and the techniques of production, the rate of profit proves a useful indicator of economic performance. In the following sections of this chapter, the components of the rate of profit are measured for the manufacturing sector as a whole and for the food and beverage sector in the six regions. The empirical analysis is guided by the theoretical arguments of the preceding three chapters and is based on the assumption that only two aggregate commodities, a capital good and a consumer good, are produced in the economy. To be consistent with this claim, the definition of the rate of profit provided in Chapter 3 is modified as

$$\pi_p = M\pi_v: \tag{7.1}$$

where M is a measure of the ability of firms to capture profits in the market (see Chapter 3):

π_p is the price rate of profit:

π_v is the value rate of profit.

In turn, the value rate of profit is defined as

$$\pi_v = \frac{S}{C+V} = \frac{(1-\lambda_2 D)L}{\lambda_1 K + \lambda_2 DLt'}:$$

$$= \frac{S/V}{t'(C/V + 1)} = \frac{(1-\lambda_2 D)/\lambda_2 D}{t'(\lambda_1 K/\lambda_2 DLt' + 1)} = \frac{e}{t'(q+1)}: \tag{7.2}$$

where S (= $(1-\lambda_2 D)L$) is the surplus value or profit:

C (= $\lambda_1 K$) is the constant capital advanced:

V (= $\lambda_2 DLt'$) is the variable capital advanced:

λ_1 is the unit value of the aggregate capital good:

λ_2 is the unit value of the aggregate consumption good:

D is the real wage:

L is the amount of labour employed in production:

K is the amount of capital employed in production:

t' (= 1/t) is a measure of the length of the turnover period and t denotes the number of turnover periods each year. Both these measures incorporate the effect of delaying the payment of wages (see Chapter 3):

e (= S/V) is the rate of exploitation:

q (= C/V) is the value composition of capital.

The methods of measuring these terms are discussed in Appendix 3. All variables are calculated on an annual basis.

The relative effects on the rate of profit of the terms in equations 7.1 and 7.2 are evaluated over the period 1955 to 1984 and over four sub-periods; 1955-1958; 1958-1974; 1974-1982 and 1982-1984. These periods were identified as break points by examination of the capacity utilisation and profit rate series for the manufacturing sector. The sub-periods 1955-1958 and 1982-1984 are separated, for they denote significant turning points in the time series, marking respectively the end and the beginning of pronounced business cycles. The influence of the components of the rate of profit are measured by estimating the following differential equations, after Webber and Tonkin (1987).

Firstly, from equation 7.1, changes in the price rate of profit can be represented by the total differential

$$d\pi_p = \pi_v.dM + M.d\pi_v. \qquad (7.3)$$

Thus, changes in the price rate of profit can be decomposed into the effects of changes in market competitiveness (dM) and changes in production efficiency ($d\pi_v$). For all the differential equations, dX, for any variable X, is to be interpreted as the absolute change in the value of that variable. Secondly, the value rate of profit can be decomposed and written as

$$d\pi_v = \frac{1}{t'(q+1)}.de - \frac{e}{t'(q+1)^2}.dq - \frac{e}{t'^2(q+1)}.dt' \ . \qquad (7.4)$$

From equation 7.4, changes in the value rate of profit can be decomposed into three effects: the effect of changes in the rate of exploitation (de): the effect of changes in the value composition of capital (dq): and the effect of changes in the turnover time of capital (dt'). In turn, the changes in the rate of exploitation and the value composition of capital can be decomposed themselves. Thus, thirdly, changes in the rate of exploitation can be expressed as

$$de = \frac{1}{\lambda_L \lambda_2}.d\lambda_2 - \frac{1}{\lambda_L D}.dD \ . \qquad (7.5)$$

Equation 7.5 decomposes the change in the rate of exploitation into the effects of the change in the unit value of consumer goods (λ_2) and the effects of changes in the real wage (dD). Fourthly, changes in the value composition of capital (VCC) are captured as

$$dq = \frac{P}{\lambda_L}.d\lambda_1 + \frac{\lambda_1}{\lambda_L}.dP - \frac{\lambda_1 P}{\lambda_L^2}.d\lambda_L. \qquad (7.6)$$

Equation 7.6 decomposes changes in the VCC into the effects of changes in the unit value of capital goods ($d\lambda_1$), changes in the unit value of labour ($d\lambda_L$) and changes in techniques of production (dP), where P is the technical composition of capital.

The technical composition of capital is defined as

$P = K/Lt'$:

$$= \frac{1}{t'}\frac{1}{R}\frac{K_u}{L} + \frac{K_c}{Lt'} :$$

where R is the capacity utilisation rate:

K_u/L is the full capacity ratio of fixed capital to labour:

K_c/Lt' is the capitalised cost of fuel and raw materials processed per hour of labour.

Fifthly, and finally, the effects of the capacity utilisation rate (dR), the turnover time of capital (dt'), the ratio of full capacity fixed capital to labour (dK_u/L) and the effect of the amount of fuel and materials processed per hour of labour (dK_c/Lt') on the technical composition of capital (TCC) are evaluated. These effects are captured by equation 7.7:

$$dP = \frac{K_u}{t'^2RL}.dt - \frac{K_u}{t'R^2L}.dR + \frac{1}{t'R}.d(K_u/L) + d(K_c/Lt') . \qquad (7.7)$$

The terms of equations 7.3-7.7 are estimated as discrete annual changes which are summed to yield the results presented below. The differentials only measure first order effects and therefore the interaction terms between the effects variables are not reported. The sum of the interaction terms equals the difference between the sum of the effects of the independent variables and the absolute change in the dependent variable.

7.3 Regional Variations in Manufacturing Performance

The analysis is separated into three sections. Section 7.3.1 examines changes in the value rate of profit and its components in six regions between 1955 and 1984. In Section 7.3.2, changes in the determinants of the price rate of profit in the same regions are discussed. This section summarises the results and explains why the rate of profit has fallen in Canadian manufacturing as a whole and why some regions have performed better than others. Section 7.3.3 briefly examines the empirical support for a number of generally accepted propositions in regional economic theory. The data is presented in figures and tables. The text will not repeat the data, but it will highlight certain results and provide some explanation for them.

7.3.1 The Rate of Profit

In this section, the terms in equations 7.1-7.7 are estimated and the relative contributions of the determinants of the rate of profit are examined. The components of the value rate of profit are analysed first (see equation 7.2).

7.3.1.1 The Rate of Exploitation

The rate of exploitation provides a measure of how the value added in production by labour is distributed between profits and wages. It is the product of two forces: the unit value of the aggregate consumer basket and the hourly real wage. In the absence of information on the consumption patterns of labour in different sectors and regions of the economy, it is assumed that the wages of all workers are spent on identical baskets of goods. The value of each of these baskets is assumed to be the same and thus the rate of exploitation varies between industries and regions as the real wage differs between them.

Figure 7.1 shows that the rate of exploitation in the manufacturing sector of Canada remained relatively constant between 1955 and 1984. At the regional level however the picture was quite different. In British Columbia (BC) for example, the exploitation rate declined by almost 22% over the same period. In Alberta too, the reduction in the rate of exploitation was relatively large (16%). In Quebec and the Atlantic region, the rate of exploitation declined more slowly, while in Ontario and the Prairies it increased.

Perhaps the most striking feature of Figure 7.1 is the marked regional variation in the exploitation rate. In the Atlantic region for example, this rate is almost 90% greater than in BC. Thus, for every dollar of value added, labour in BC receives about 45% more in wages than labour in the Atlantic region. Regional differences in this variable appear to be increasing.

The determinants of the rate of exploitation are shown in Table 7.1. Over all four sub-periods, reductions in the unit value of the aggregate consumer good (see Figure 7.2) tended to depress the value of labour-power and raise the rate of exploitation. The strength of this tendency was greatest between 1958 and 1974. Hourly real wages increased strongly in all regions until the mid-1970s (see Figure 7.3) offsetting the effects of technical change on the value of consumer goods. After 1977 real wages declined, particularly in Ontario and the Atlantic region, and the rate of exploitation increased in all regions.

FIGURE 7.1: THE RATE OF EXPLOITATION (ALL INDUSTRIES)

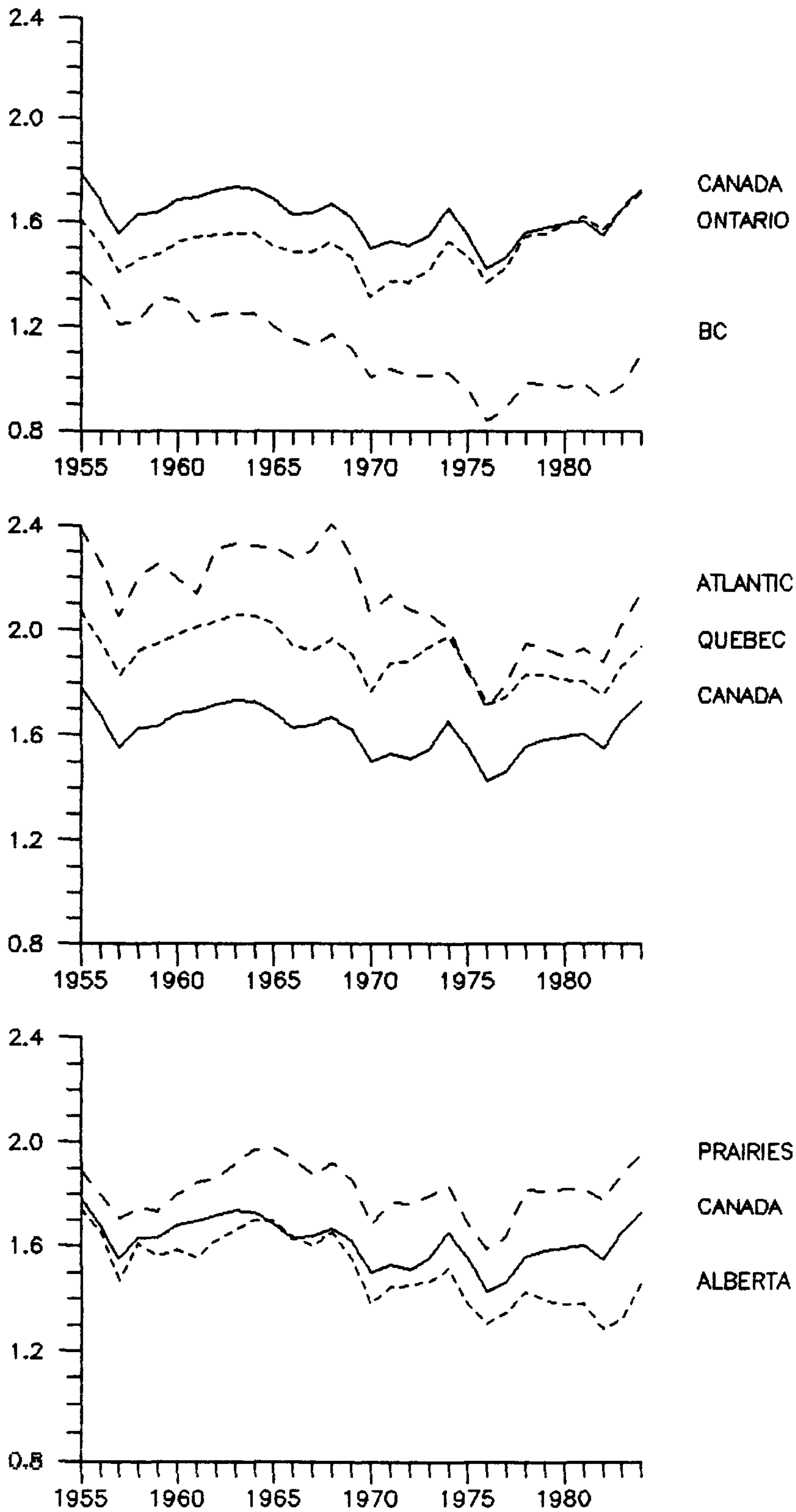


TABLE 7.1: DETERMINANTS OF THE RATE OF EXPLOITATION (ALL INDUSTRIES)

PERIOD / REGION	de	EFFECT OF THE VALUE OF CONSUMER GOODS	EFFECT OF THE REAL WAGE
1955-1958			
CANADA	-0.1506	0.0419	-0.2045
ATLANTIC	-0.1886	0.0447	-0.2554
QUEBEC	-0.1508	0.0429	-0.2061
ONTARIO	-0.1521	0.0364	-0.1984
PRAIRIES	-0.1464	0.0418	-0.1970
ALBERTA	-0.1314	0.0357	-0.1868
BC	-0.1743	0.0329	-0.2172
1958-1974			
CANADA	0.0239	1.1566	-1.1818
ATLANTIC	-0.1921	1.3795	-1.6618
QUEBEC	0.0534	1.2683	-1.2716
ONTARIO	0.0662	1.0607	-1.0450
PRAIRIES	0.0867	1.2124	-1.1842
ALBERTA	-0.0991	1.0986	-1.2594
BC	-0.2018	0.9284	-1.1850
1974-1982			
CANADA	-0.1041	0.0930	-0.2167
ATLANTIC	-0.1293	0.1413	-0.3019
QUEBEC	-0.2237	0.1437	-0.3900
ONTARIO	0.0445	0.1222	-0.0954
PRAIRIES	-0.0544	0.1342	-0.2143
ALBERTA	-0.2239	0.1221	-0.3653
BC	-0.0930	0.0966	-0.2079
1982-1984			
CANADA	0.1762	0.2041	-0.0357
ATLANTIC	0.2623	0.2278	0.0239
QUEBEC	0.1888	0.2170	-0.0361
ONTARIO	0.1428	0.2019	-0.0657
PRAIRIES	0.1830	0.2184	-0.0431
ALBERTA	0.1699	0.1786	-0.0185
BC	0.1674	0.1509	0.0076

FIGURE 7.2: THE UNIT VALUE OF THE AGGREGATE CONSUMER GOOD

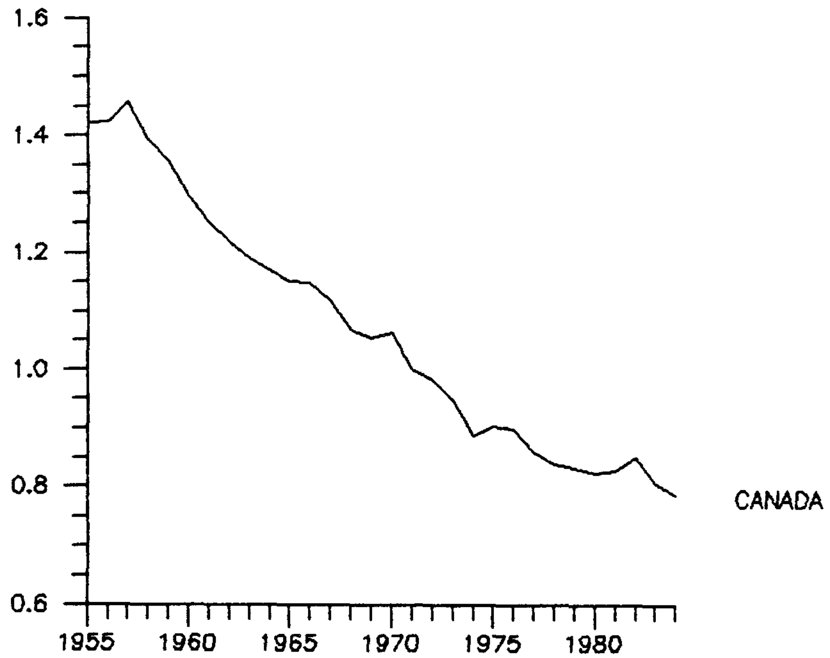
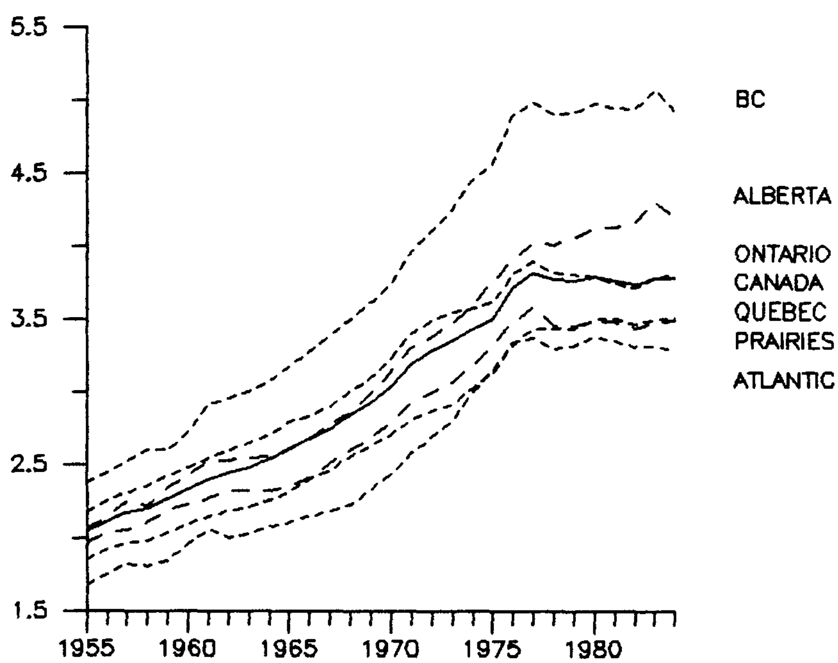


FIGURE 7.3: THE HOURLY REAL WAGE (ALL INDUSTRIES)



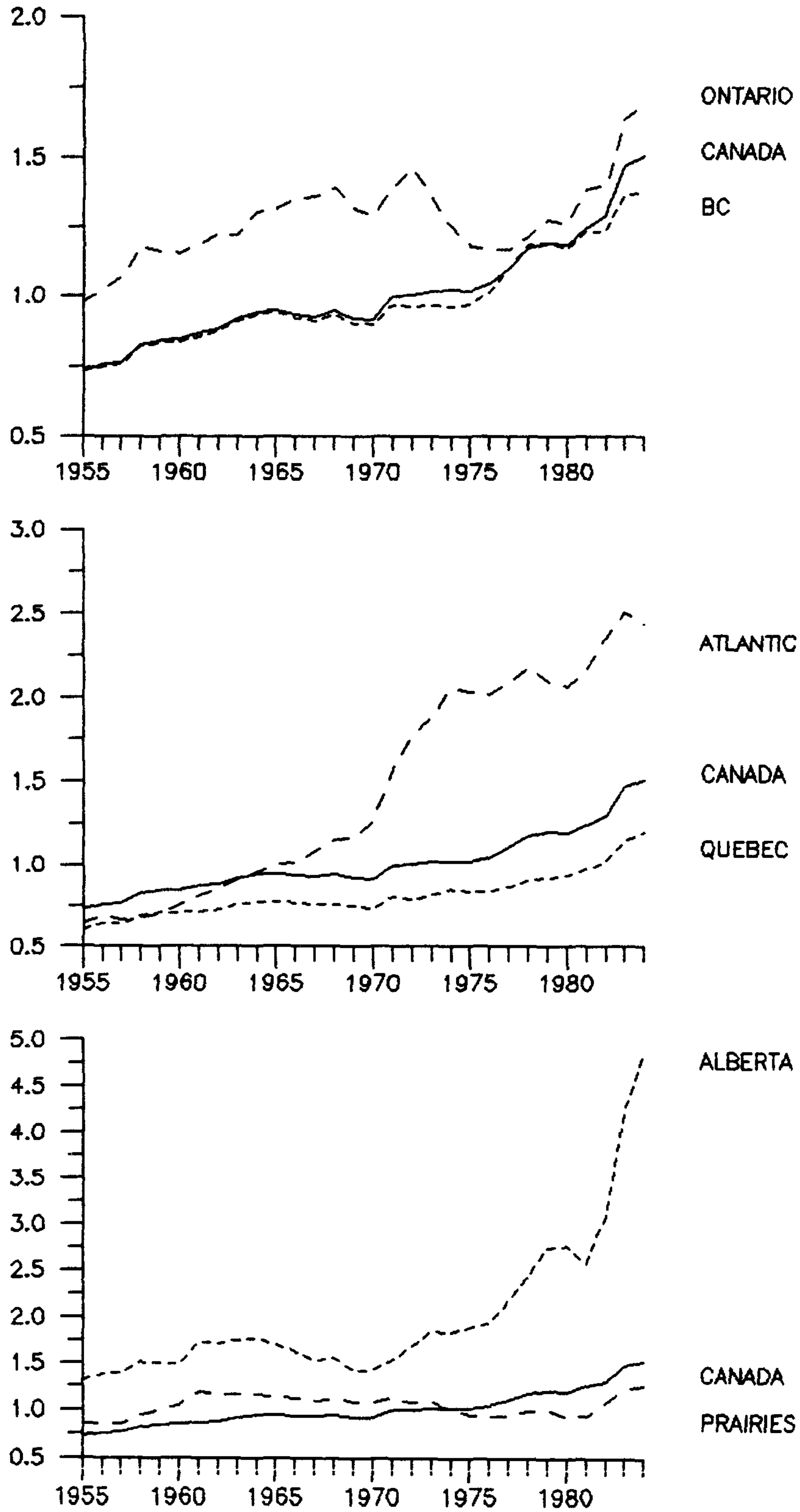
The attack on real wages after the mid-1970s was likely prompted by a marked reduction in the rate of profit. The pace of technical change slowed considerably after 1974 and thus real wage gains translated increasingly into lower profits. The long post-war boom, fuelled in part by rising real wages but a steady rate of exploitation appeared to be over.

7.3.1.2 The Value Composition of Capital

The value composition of capital (VCC) is the ratio of the constant capital advanced in production to the variable capital advanced. The VCC measures the effects of technical changes on the rate of profit; indirectly through changes in the unit values of the aggregate capital good and the unit value of labour-power; and directly through changes in the technical composition of capital (see equation 7.6). It is expressed as an index with a base value for Canada of 100 in 1971.

In contrast to the rate of exploitation, the VCC exhibits a marked increase in all regions except the Prairies (see Figure 7.4). Nevertheless, the history of the VCC is quite dissimilar across Canada. In the Prairies for example, this variable increased most rapidly around 1960, in the Atlantic region it increased quickest in the 1970s, while in Alberta it rose fastest after 1981. Alberta recorded the largest absolute increase in the VCC between 1955 and 1984, a rise of almost 270%. The Atlantic region boasted the second largest absolute gain, though in relative terms it outperformed Alberta. The Prairie region lagged behind all others in adopting technological improvements, registering an increase in the VCC of only 26.8%. Not only did the pace

FIGURE 7.4: THE VALUE COMPOSITION OF CAPITAL (ALL INDUSTRIES)



of changes in the VCC vary between regions, it also varied over time. On average in Canada, the VCC remained relatively constant between 1958 and 1974. After 1974, the pace of the increase in the VCC was more rapid, averaging about .6 units per year until 1982 and then accelerating dramatically to over 2.3 units per annum. Figure 7.4 shows that this history was not the same in all regions.

Regional variations in the VCC, like the rate of exploitation appear to be increasing. This might be due to greater regional specialisation, the marked rise in this variable in Alberta for instance strongly influenced by the recent development of the petroleum and coal industries. The dramatic, and perhaps unexpected, increase of the VCC in the Atlantic region, is probably the result of regional policies (Savoie, 1986 and Anderson and Rigby, forthcoming).

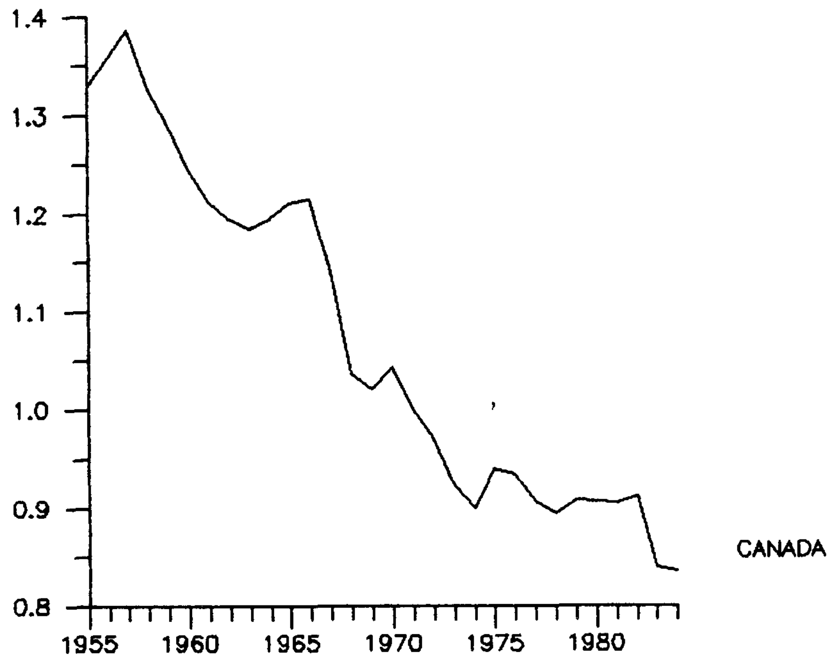
Table 7.2 shows that the increases in the VCC were dominated by the direct effects of technical change, measured as changes in the technical composition of capital (TCC). In all regions, over all sub-periods, the TCC exerted a positive influence on the VCC, and over most of the periods the effects of the TCC on the VCC were several times greater in magnitude than those of the other effects variables. In most regions the effects of the TCC on the VCC remained steady throughout the 1960s and 1970s, increasing after 1982.

Technical changes that raise the TCC and contribute to the change in the VCC also cause the unit value of capital goods to fall (see Figure 7.5). The unit value of the aggregate capital good is almost identical in all regions and thus only the Canadian average is shown. This second influence of technical change exerts a downward pressure on the VCC that

TABLE 7.2: DETERMINANTS OF THE VALUE COMPOSITION OF CAPITAL (ALL INDUSTRIES)

PERIOD / REGION	dq	EFFECT OF THE VALUE OF CAPITAL GOODS	EFFECT OF THE TECHNICAL COMPOSITION OF CAPITAL	EFFECT OF THE VALUE OF LABOUR POWER
1955-1958				
CANADA	2.1286	0.0011	3.0714	-0.9150
ATLANTIC	0.8503	-0.0735	1.7898	-0.8902
QUEBEC	1.9293	0.0230	2.6158	-0.6945
ONTARIO	1.7933	0.0486	2.7637	-0.9835
PRAIRIES	1.2620	-0.0733	3.0242	-0.9751
ALBERTA	4.2510	-0.3573	6.1122	-1.5319
BC	4.4950	-0.2451	6.5710	-1.6676
1958-1974				
CANADA	4.1803	-7.5302	12.0150	0.1368
ATLANTIC	29.4628	-8.5438	41.9000	-2.3923
QUEBEC	3.3854	-5.9352	9.4331	-0.5702
ONTARIO	2.9771	-7.2433	10.2330	0.4207
PRAIRIES	1.2620	-8.2977	9.4228	0.6014
ALBERTA	7.0120	-12.2730	21.2280	-1.0837
BC	1.5010	-10.5660	15.5950	-2.8722
1974-1982				
CANADA	5.9204	0.3674	6.5112	-0.9197
ATLANTIC	6.4287	0.2765	8.7203	-2.2030
QUEBEC	3.7570	-1.5876	8.8084	-0.6466
ONTARIO	5.9208	0.1530	5.3235	0.4799
PRAIRIES	1.3638	-0.3116	2.1856	-0.5591
ALBERTA	26.9740	0.4744	31.3050	-4.5153
BC	3.1621	0.0690	4.5196	-1.4987
1982-1984				
CANADA	4.5913	-2.3917	5.2933	1.9343
ATLANTIC	1.7983	-4.0356	1.6381	4.4381
QUEBEC	3.8406	-1.8653	4.3462	1.5008
ONTARIO	2.9824	-2.3621	4.1012	1.4815
PRAIRIES	3.8812	-1.9929	4.5118	1.5344
ALBERTA	37.9580	-4.9799	38.0790	6.0262
BC	6.4308	-2.4624	6.4596	2.7451

FIGURE 7.5: THE UNIT VALUE OF THE AGGREGATE CAPITAL GOOD



was strongest through the 1960s and after 1982. This would appear to be due to the varying strength of the different determinants of the TCC in these periods (see the following section). The regional strength of this counter-tendency to increases in the VCC vary a great deal. In the Prairie region for example, reductions in the value of capital goods suppress almost 50% of the impact of the TCC on the VCC, while in Alberta they suppress the effects of only 18% of the TCC. Again this may be because the strength of different types of technical change vary between regions, and because only certain kinds of changes that increase the TCC reduce the unit values of commodities.

The final component of changes in the VCC is the effect of changes in the unit value of labour-power (Figure 7.6 and Table 7.2). Between 1955 and 1984, reductions in the unit value of labour power had a negligible effect on the VCC, though after 1977 they contributed to the general increase in the VCC. This was chiefly the result of reductions in the real wage during this latter period.

7.3.1.2.1 The Technical Composition of Capital

The TCC is defined as the ratio of the physical amount of constant capital to the physical amount of labour employed in production. From equation 7.7, the TCC has four components: the turnover times of capital; the capacity utilisation rate; the full capacity fixed capital to labour ratio and the amount of materials processed per hour of labour. The TCC is expressed as an index with a base value of 100 in 1971 for Canadian manufacturing as a whole.

The TCC increased in all regions of Canada between 1955 and 1984 (see Figure 7.7). In Alberta the rise in the TCC was most rapid, increasing from an index value of 56.2 in 1955 to 368.6 in 1984, an increase of some 555%. On average in Canadian manufacturing, the TCC increased by about 237% over the same period. In both the Atlantic region and BC, the rise in this variable was above the Canadian average. In all other regions the TCC increased significantly slower than the average rate.

In general over the thirty years, all four effects variables exerted a positive influence on the TCC, although Table 7.3 reveals that during certain sub-periods changes in the turnover time of capital and the capacity utilisation rate dampened the rise in the TCC. Of the

FIGURE 7.6: THE VALUE OF LABOUR-POWER (ALL INDUSTRIES)

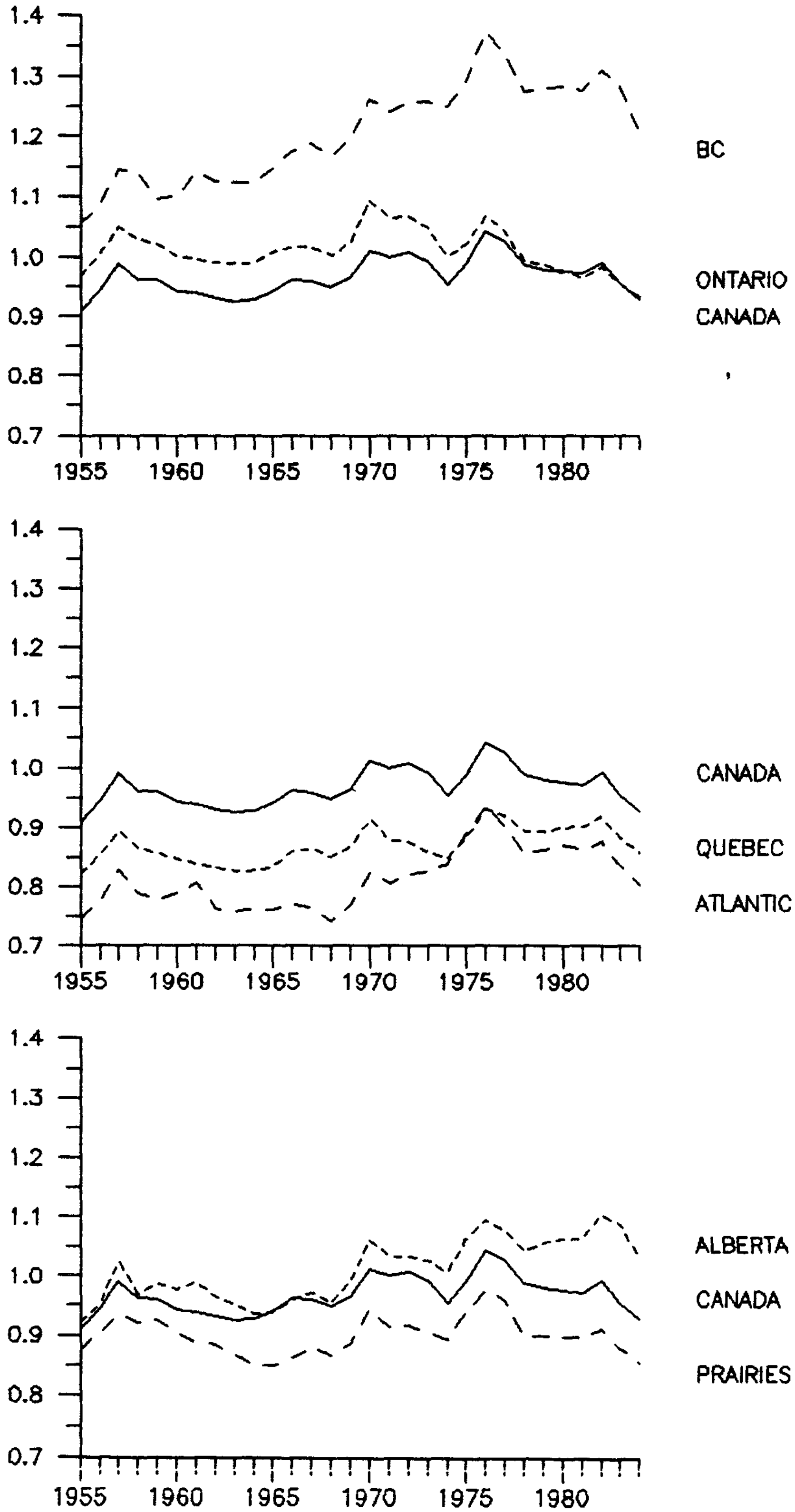


FIGURE 7.7: THE TECHNICAL COMPOSITION OF CAPITAL (ALL INDUSTRIES)

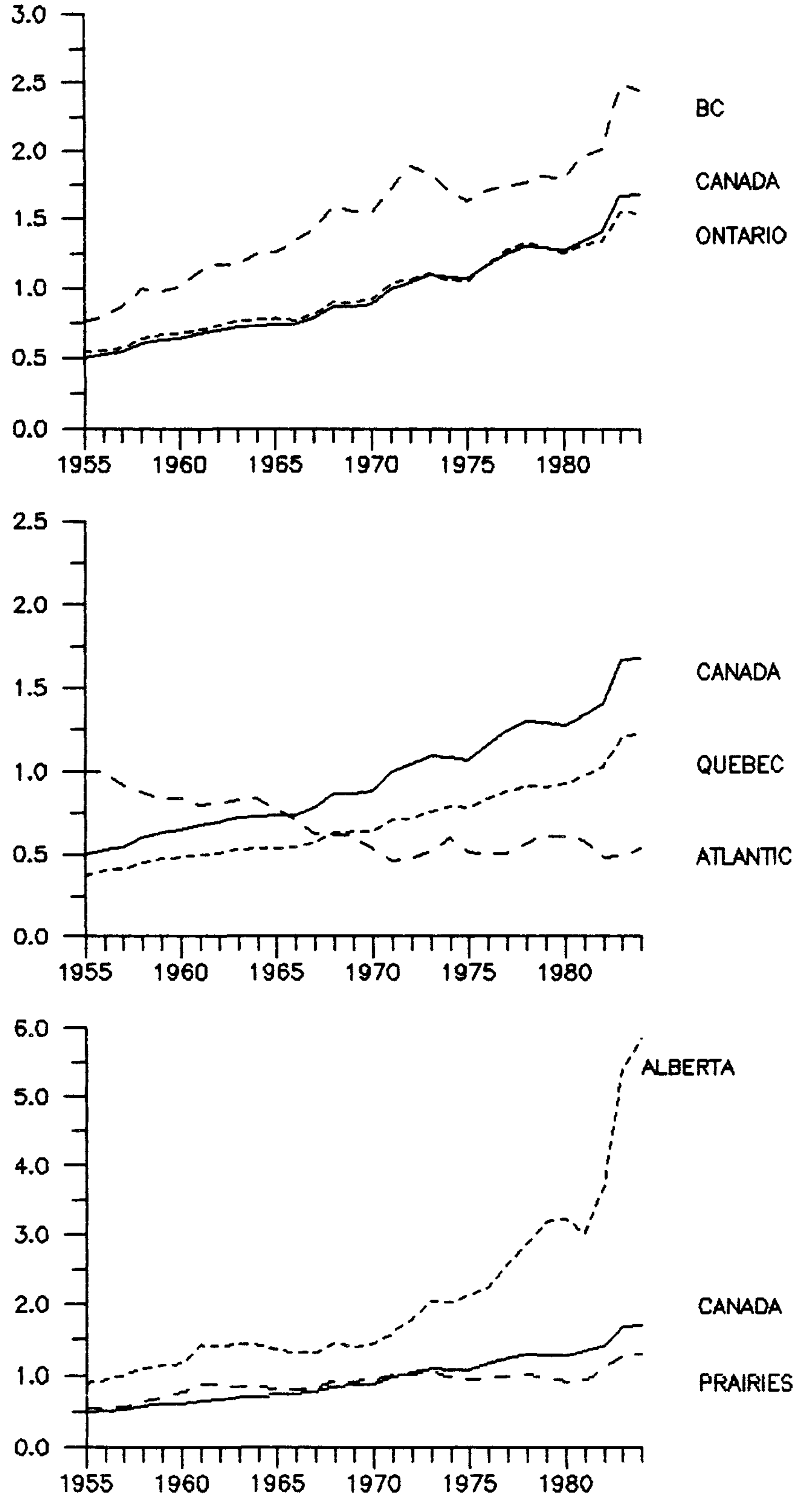


TABLE 7.3: DETERMINANTS OF THE TECHNICAL COMPOSITION OF CAPITAL (ALL INDUSTRIES)

PERIOD / REGION	dP	EFFECT OF TURNOVER TIMES	EFFECT OF CAPACITY UTILISATION	EFFECT OF TECHNICAL CHANGE	EFFECT OF LABOUR INTENSITY
1955-1958					
CANADA	6.8870	-1.2576	5.4011	1.4545	0.5547
ATLANTIC	3.2110	-1.7601	2.6263	1.4126	0.6384
QUEBEC	5.2835	-0.5624	3.8539	0.8918	0.6553
ONTARIO	6.6060	-1.8802	5.3310	1.8280	0.7896
PRAIRIES	6.5026	-0.5942	4.8915	0.9584	0.7587
ALBERTA	13.7010	3.7268	4.3175	3.5139	1.4484
BC	16.7200	-2.6900	14.9380	1.4071	0.6761
1958-1974					
CANADA	33.2100	6.9224	-4.0521	22.3540	5.7299
ATLANTIC	100.8630	31.8410	-0.1913	52.6440	8.7058
QUEBEC	23.5974	3.1671	-1.1798	15.3880	5.3104
ONTARIO	29.3640	6.2600	-5.6150	20.5120	5.8643
PRAIRIES	22.4341	-1.5196	-2.0658	17.8750	5.0549
ALBERTA	63.3220	26.0620	-27.8160	48.9160	11.0380
BC	49.1870	13.2610	-26.7870	48.4190	6.6373
1974-1982					
CANADA	22.5880	-8.0775	16.3760	8.2508	4.1458
ATLANTIC	25.9980	-0.1506	18.5790	-1.0383	1.7008
QUEBEC	23.5974	3.1671	-1.1798	15.3880	5.3104
ONTARIO	18.9290	-11.9440	17.2580	7.2220	3.0412
PRAIRIES	7.2108	-2.5491	4.5559	1.8266	0.9366
ALBERTA	116.3530	-6.2392	59.8090	35.3420	7.8549
BC	20.7530	-22.9800	-11.7620	12.4280	1.4657
1982-1984					
CANADA	18.4810	17.8400	-8.9696	5.5489	0.1354
ATLANTIC	4.7200	5.3947	-14.6200	10.7900	1.2326
QUEBEC	14.1282	12.1180	-2.0448	1.8191	0.3618
ONTARIO	14.1330	18.7780	-15.0370	6.1001	1.2051
PRAIRIES	14.7352	11.3270	2.5722	-1.0916	-0.0067
ALBERTA	147.7040	46.9770	27.0450	42.0330	6.3085
BC	29.5880	21.9800	-11.7620	12.4280	1.4657

variables affecting the TCC, by far the most significant has been the increase in the full capacity ratio of fixed capital to labour. This represents perhaps better than the other effects, the impact of "pure" technical changes in manufacturing, being the embodiment of new techniques of production in additions to the capital stock. Increases in the capacity adjusted capital-labour ratio account for almost 50% of the rise in the TCC in most regions between 1955 and 1984. Table 7.3 shows how the influence of this variable has changed in the regions between the sub-periods.

Increases in the amount of energy and materials processed per hour of labour were responsible for about 13% of the increase in the TCC on average in Canada from 1955 to 1984. Regional and temporal variations in this measure of the intensity of the labour process were not as great as the variations in the capital-labour ratio over the same period.

Changes in the length of the turnover period have exerted a less straightforward effect on the TCC than either of the two variables just discussed. In general, the turnover time of capital is closely related to the business cycle, decreasing in upswings and lengthening during downswings. For the entire manufacturing sector, changes in turnover times exerted about 1.5 times the effect of changes in the intensity of the labour process on the TCC. After 1982 though, in all regions except the Atlantic, reductions in the length of the turnover period had a greater impact on the TCC than technical change proper.

Changes in the capacity utilisation rate have also exerted a significant though uneven influence on the TCC. In all regions, capacity utilisation rates fell during the downswing of the late-1950s (see Figure

7.8). At this time changes in capacity utilisation dominated the movement of the TCC but this was largely because the pace of technical change was slow. Between 1974 and 1982, reductions in capacity utilisation once more dominated the movement of the TCC in all regions except Quebec and BC. These data show that investment in new technology is not necessarily the dominant influence on the TCC. In fact in Ontario throughout the second half of the 1970s, reductions in capacity utilisation were responsible for over 90% of the increase in the TCC. In the Atlantic region, Alberta and the Prairies, reductions in the use of existing fixed capital were also the primary cause of the rising TCC in the 1970s.

7.3.1.3 The Turnover Time of Capital

The turnover time of capital provides an indication of the average length of time between advancing capital to finance production and recouping that investment. As such the turnover time is a measure of the speed of production and therefore a useful indicator of economic performance; the shorter the turnover time the more capital that can be put in process for a given outlay. The inverse of the turnover time yields an estimate of the number of turnovers in a given period, in this case one year.

Figure 7.9 shows the history of the number of turnovers in manufacturing in the six regions of Canada between 1955 and 1984. The number of turnovers each year has increased in all regions over the thirty years. The increase in the speed of production has been most rapid in Alberta and in the Atlantic region, those areas that experienced

FIGURE 7.8: THE CAPACITY UTILISATION RATE (ALL INDUSTRIES)

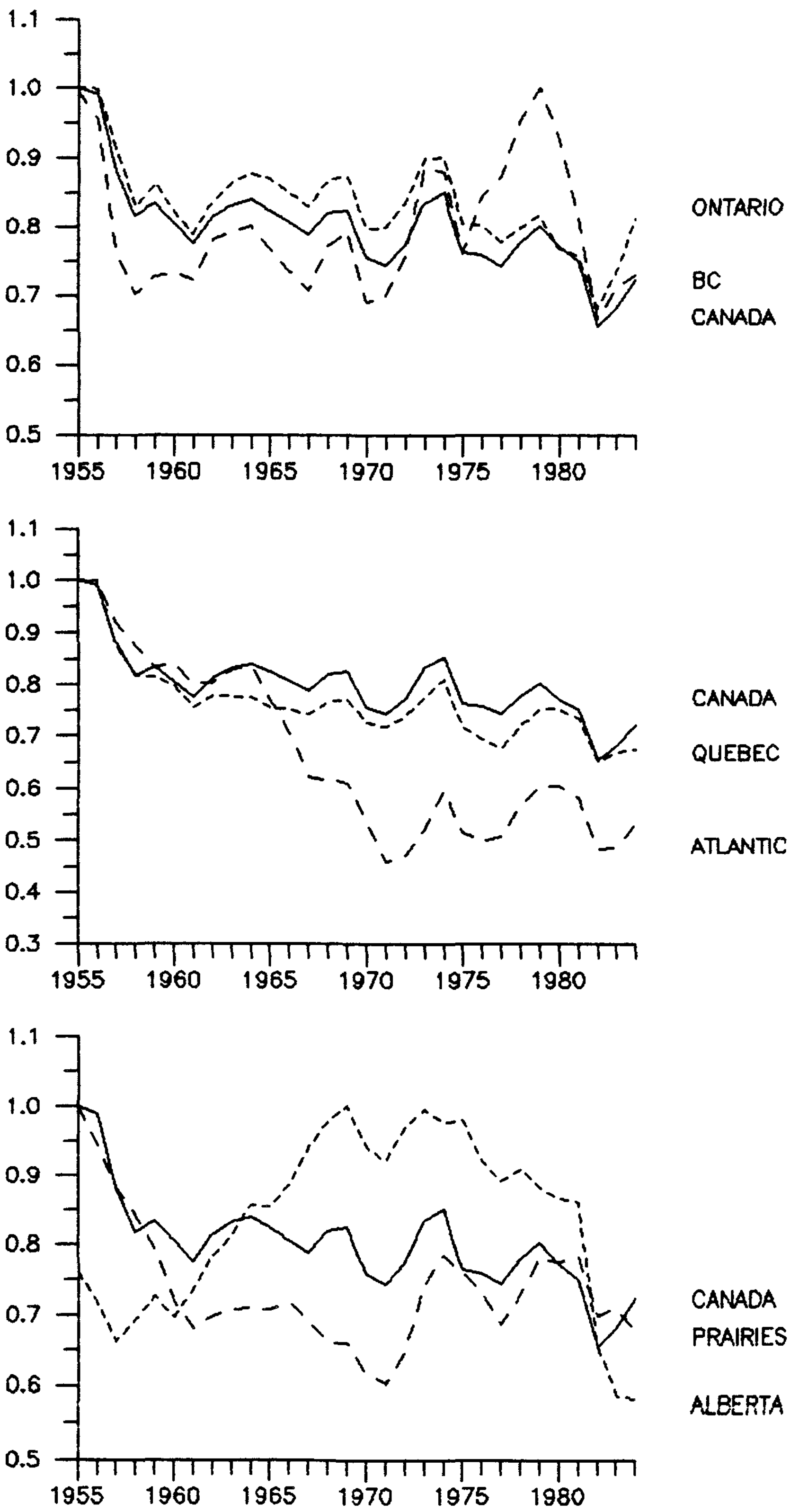
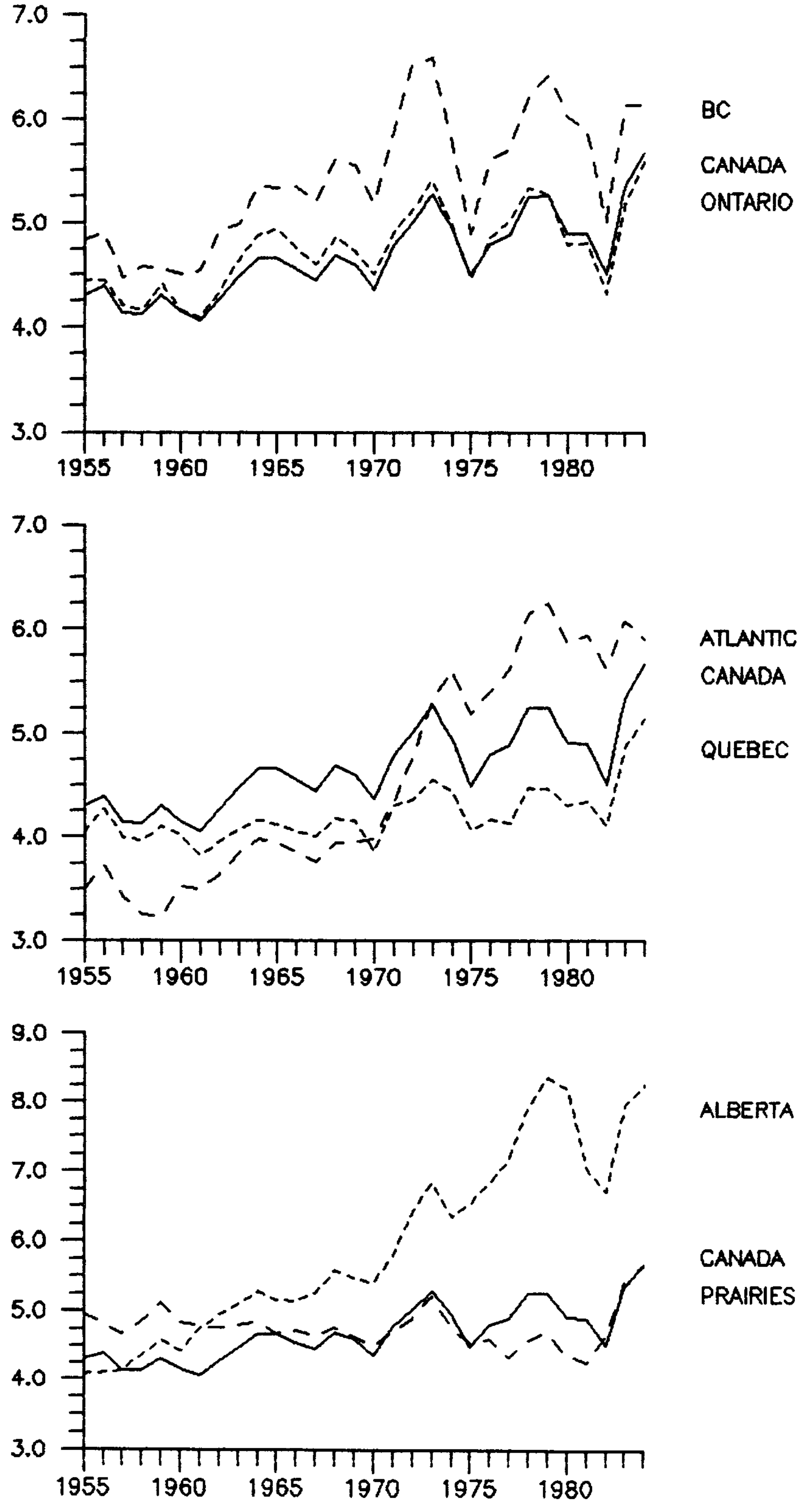


FIGURE 7.9: THE ANNUAL NUMBER OF TURNOVERS (ALL INDUSTRIES)



the greatest increase in the VCC, though it also increased relatively rapidly in British Columbia which experienced a sluggish increase in the VCC. On average, in Canadian manufacturing, the number of turnovers each year increased by approximately 32% between 1955 and 1984.

7.3.1.4 The Value Rate of Profit

The value rate of profit measures the return on capital advanced when all commodities exchange in the market at their respective values or expected prices (see Chapter 3). The value rate of profit measures efficiency in production for the vagaries of the market are not captured by this variable. The components of the value rate of profit are given by equation 7.2. The history and determinants of these variables was outlined above. This section summarises their effects.

Figure 7.10 shows that the value rate of profit in Canadian manufacturing decreased in all regions between 1955 and 1984. In the Atlantic region the reduction in profitability was more severe than elsewhere, falling by almost 58%. In Alberta, BC and to a lesser extent Quebec, the decline in profitability was also greater than average. In Ontario and the Prairies, the rate of profit declined but at a slower pace than the Canadian average. Figure 7.10 also reveals marked differences in the level of profitability between regions. On average between 1955 and 1984, the value rate of profit was more than twice as high in Quebec as Alberta. This is largely because the VCC in Quebec is significantly lower than in Alberta. In the Atlantic region, the relatively high value rate of profit in the 1950s results from a low VCC and high rates of exploitation.

FIGURE 7.10: THE VALUE RATE OF PROFIT
(ALL INDUSTRIES)

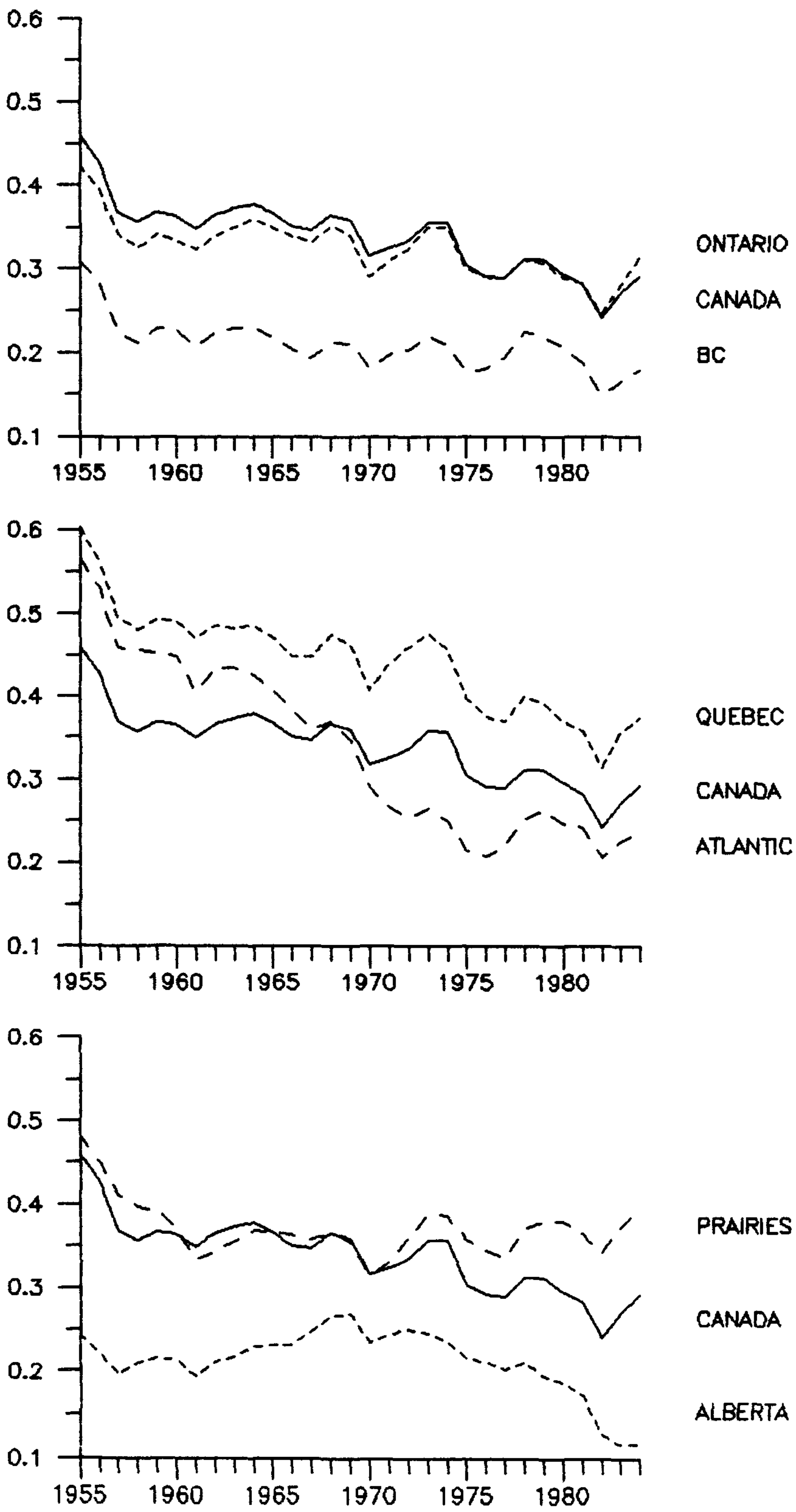


Table 7.4 examines how the variables discussed in the four sections above have influenced the value rate of profit in Canada. Increases in the VCC in all regions have dominated the movements of the profit rate. Had the rate of exploitation and turnover times not changed for example, increases in the VCC would have caused the value rate of profit in Canada to decrease by nearly 23 percentage points, or from almost 46% in 1955 to 23% in 1984. Reductions in turnover times opposed the fall in the rate of profit in all regions, though the effects of speeding up the production process were always overwhelmed by the rising VCC. Only in Ontario and the Prairies did the rate of exploitation increase between 1955 and 1984, tending to raise the rate of profit. In all other regions, the rate of exploitation decreased, exacerbating the reduction in profitability.

These results question Marxist claims that increases in the rate of exploitation are a significant counter-tendency to reductions in the rate of profit. The findings here accord with those of Webber and Tonkin (1987). They also provide empirical support for the arguments in Chapter 5, that technical changes that increase the TCC do not automatically cause the rate of exploitation to rise.

7.3.1.5 Price-Value Deviations

In Chapter 3 it was argued that firms compete for profits in the market as well as in production. The forms of competition in the two spheres are not the same. In the market, firms may gain (lose) profits as they acquire inputs at prices below (above) the market rate, that is below (above) their expected price or value. In addition, selling output

TABLE 7.4: DETERMINANTS OF THE VALUE RATE OF PROFIT (ALL INDUSTRIES)

PERIOD / REGION	$d\pi_V$	EFFECT OF THE RATE OF EXPLOITATION	EFFECT OF THE VALUE COMPOSITION OF CAPITAL	EFFECT OF TURNOVER TIMES
1955-1958				
CANADA	-0.1020	-0.0400	-0.0494	-0.0181
ATLANTIC	-0.1083	-0.0463	-0.0317	-0.0375
QUEBEC	-0.1211	-0.0451	-0.0735	-0.0103
ONTARIO	-0.0978	-0.0407	-0.0372	-0.0250
PRAIRIES	-0.0849	-0.0375	-0.0399	-0.0121
ALBERTA	-0.0332	-0.0182	-0.0300	0.0134
BC	-0.0961	-0.0381	-0.0500	-0.0181
1958-1974				
CANADA	-0.0014	0.0058	-0.0702	0.0520
ATLANTIC	-0.2072	-0.0234	-0.3869	0.1697
QUEBEC	-0.0244	0.0130	-0.0910	0.0389
ONTARIO	0.0252	0.0159	-0.0474	0.0432
PRAIRIES	-0.0104	0.0199	-0.0285	-0.0172
ALBERTA	0.0265	-0.0180	-0.0487	0.0785
BC	-0.0011	-0.0383	-0.0129	0.0351
1974-1982				
CANADA	-0.1150	-0.0207	-0.0684	-0.0391
ATLANTIC	-0.0444	-0.0158	-0.0314	-0.0080
QUEBEC	-0.1434	-0.0492	-0.0663	-0.0406
ONTARIO	-0.1049	0.0088	-0.0732	-0.0556
PRAIRIES	-0.0447	-0.0121	-0.0230	-0.0199
ALBERTA	-0.1084	-0.0320	-0.1096	0.0137
BC	-0.0610	-0.0147	-0.0239	-0.0405
1982-1984				
CANADA	0.0505	0.0280	-0.0382	0.0533
ATLANTIC	0.0313	0.0288	-0.0070	0.0081
QUEBEC	0.0589	0.0346	-0.0526	0.0677
ONTARIO	0.0676	0.0231	-0.0265	0.0617
PRAIRIES	0.0540	0.0357	-0.0550	0.0647
ALBERTA	-0.0139	0.0151	-0.0633	0.0241
BC	0.0295	0.0280	-0.0306	0.0274

for prices above (below) the market rate will also boost (reduce) profits. Capturing extra profit in the market is one means by which a firm may push its real or price rate of profit above its value rate.

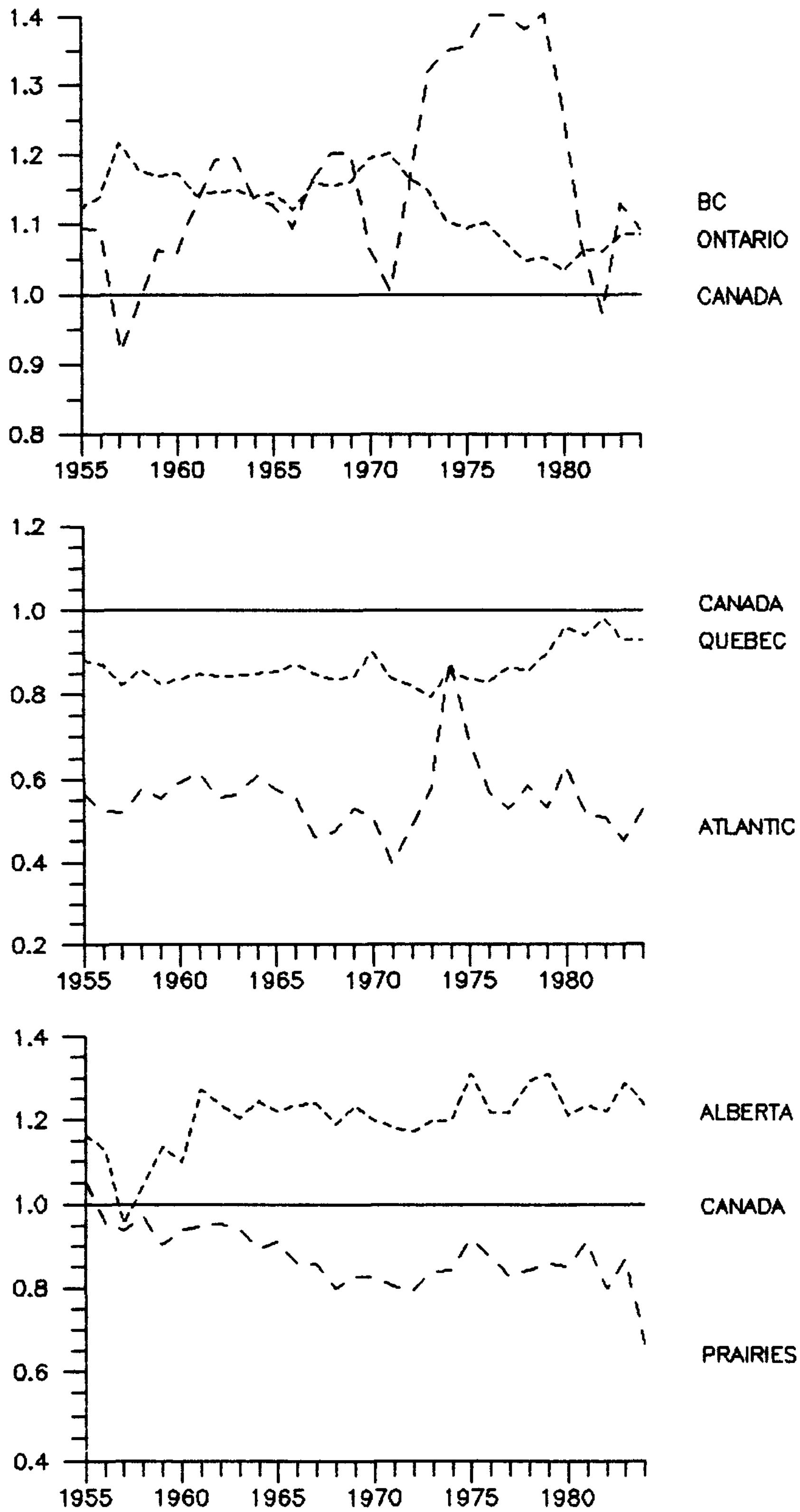
Figure 7.11 shows that the ability of firms to capture profit in the market varies widely between regions. Between 1955 and 1984, all regions except the Prairies were consistently either net winners or net losers in the market. The Prairie region suffered the worst decline in market performance over the thirty years. The Atlantic region and Ontario also suffered a deterioration in market performance, while all other regions improved their market standing. The sharp peak in the price-value profit rate deviation in the Atlantic region and the strong performance of BC through the 1970s are both attributable to marked increases in labour productivity.

In general these results accord with the theory of value transfer in Marxist economics (see Foot and Webber, 1983). That is, value will be captured by firms with higher than average value compositions of capital and those with lower than average rates of exploitation. The data and theoretical arguments of this thesis also suggest that the theory of unequal exchange should be modified to take account of variations in the turnover time of capital.

7.3.2 The Price Rate of Profit: A Summary of Regional Manufacturing Performance in Canada

The price rate of profit is the rate of return on capital advanced that is actually realised by firms, prior to taxation and before payments to rent and interest. It is the product of the value rate of

FIGURE 7.11: THE PRICE-VALUE DEVIATION (ALL INDUSTRIES)



profit and the price-value deviation and as such captures the effects of all the variables discussed above.

Figure 7.12 shows that the price rate of profit declined in all regions between 1955 and 1984. Regional variations in profitability are significant. In absolute terms, Quebec has performed best over the thirty years, posting an average rate of profit of 39.2%. Ontario ranks second, with an average rate of profit between 1955 and 1984 of almost 37%. The Atlantic region fared worst over this period, averaging a profit rate of only 19.9%, while the Canadian average was 34.3%. British Columbia, Alberta and the Prairies, all performed worse than the Canadian average. In terms of changing performance levels, the Atlantic provinces again fared worst over the thirty years, experiencing a decline in the annual price rate of profit of nearly 61%. The reduction in levels of profitability was also severe in Alberta (-50.2%), in the Prairies (-48%) and in British Columbia (-41.8%). Both Ontario and Quebec performed better than average in this category, suffering a decline in manufacturing profitability of only 28.3% and 34.7% respectively. The average reduction in the manufacturing rate of profit between 1955 and 1984 was 36.6%.

Table 7.5 shows the relative effects on the price rate of profit of production and market based performance in each region between 1955 and 1984. In the Prairies, poor market performance was the main cause of the reduction in profits. For other regions, market performance was more variable. In general most regions perform worst in the market during periods of recession. In the late-1950s and late-1970s for example, most regions lost profit in the market. This may indicate that competition

FIGURE 7.12: THE PRICE RATE OF PROFIT
(ALL INDUSTRIES)

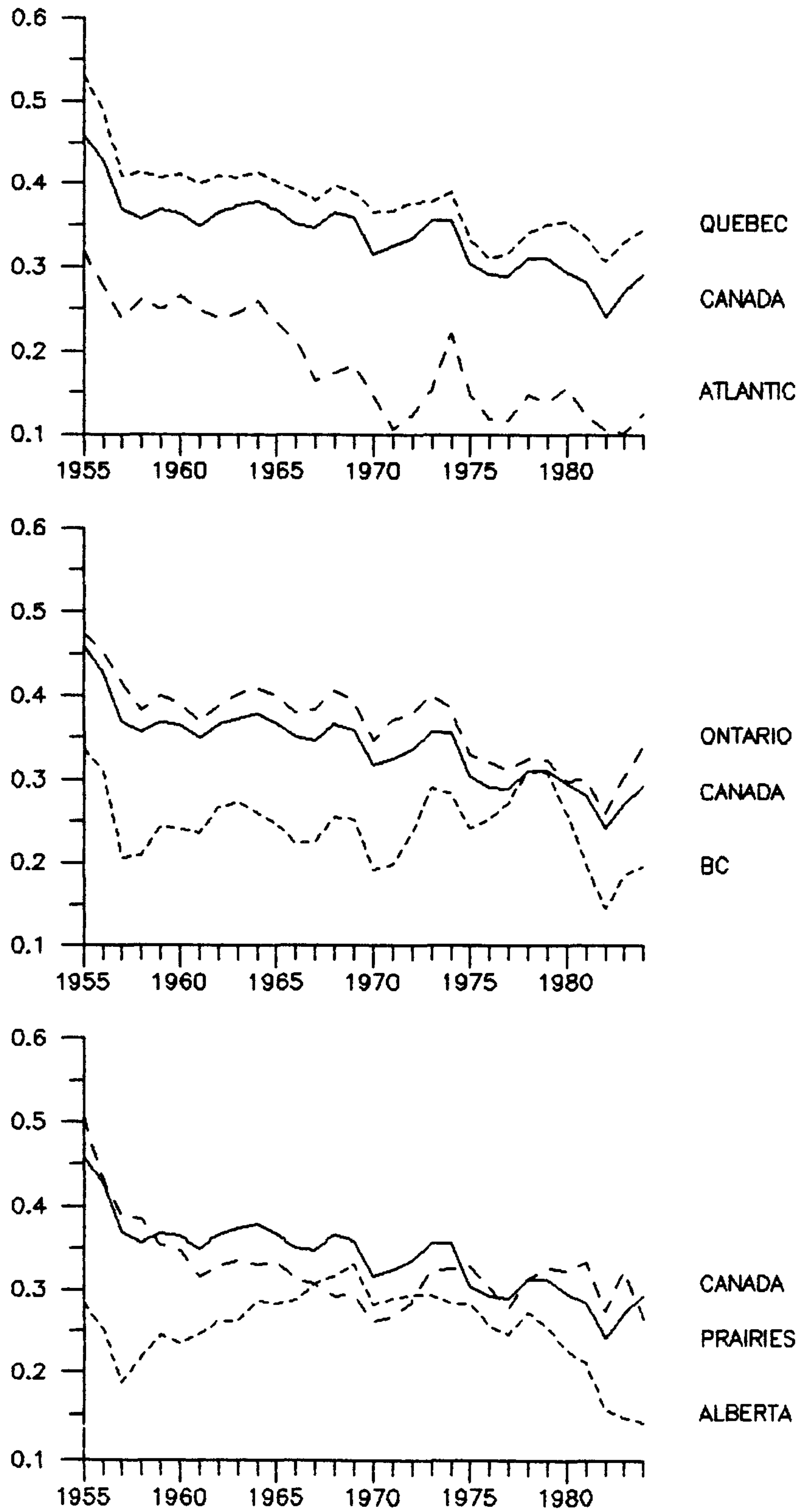


TABLE 7.5: DETERMINANTS OF THE PRICE RATE OF PROFIT (ALL INDUSTRIES)

PERIOD / REGION	$d\pi_p$	EFFECT OF PRICE-VALUE DEVIATION	EFFECT OF VALUE RATE OF PROFIT
1955-1958			
CANADA	-0.1020	0.0000	-0.1020
ATLANTIC	-0.0560	0.0006	-0.0580
QUEBEC	-0.1172	-0.0150	-0.1052
ONTARIO	-0.0916	0.0245	-0.0914
PRAIRIES	-0.1216	-0.0409	-0.0840
ALBERTA	-0.0646	-0.0304	-0.0407
BC	-0.1276	-0.0343	-0.1027
1958-1974			
CANADA	-0.0014	0.0000	-0.0014
ATLANTIC	-0.0421	0.0714	-0.1122
QUEBEC	-0.0238	0.0031	-0.0178
ONTARIO	0.0031	-0.0250	0.0308
PRAIRIES	-0.0609	-0.0452	-0.0123
ALBERTA	0.0646	0.0327	0.0347
BC	0.0751	0.0734	-0.0066
1974-1982			
CANADA	-0.1150	0.0000	-0.1150
ATLANTIC	-0.1167	-0.0881	-0.0361
QUEBEC	-0.0820	-0.0484	-0.1276
ONTARIO	-0.1254	-0.0122	-0.1131
PRAIRIES	-0.0534	-0.0137	-0.0413
ALBERTA	-0.1273	0.0076	-0.1345
BC	-0.1389	-0.0792	-0.0679
1982-1984			
CANADA	0.0505	0.0000	0.0505
ATLANTIC	0.0205	0.0054	0.0152
QUEBEC	0.0384	-0.0164	0.0570
ONTARIO	0.0794	0.0060	0.0725
PRAIRIES	-0.0086	-0.0509	0.0447
ALBERTA	-0.0151	0.0029	-0.0170
BC	0.0503	0.0175	0.0309

intensifies during periods of crisis.

In all regions except the Prairies, reductions in the value rate of profit were the principal cause of the decline in the price rate of profit. The value rate of profit fell consistently in most regions between 1955 and 1982 and this was almost entirely the result of increases in the VCC.

The post-war history of manufacturing in Canada provides strong support for Marx's classic thesis of the falling rate of profit. Between 1955 and 1977 rising real wages mollified the demands of an increasingly strong labour force and also provided a ready market for consumer goods. Rising real wages did not themselves squeeze profits for capitalists introduced technical changes that reduced the unit value of consumer goods. Thus, the rate of exploitation remained relatively constant.

The technical changes introduced by capital were predominantly of a labour-saving kind and these exerted a negative influence on the rate of profit. In the mid-1970s, in response to declining profits, the pace of technical change slowed and capacity utilisation rates were reduced. The decrease in rates of capacity utilisation largely took the place of labour-saving technical changes, causing the TCC to rise and thus reducing the rate of profit. Unlike technical change proper however, reductions in capacity utilisation rates do not decrease the values of commodities and so rates of exploitation fell around 1974 as real wages continued to rise. The rising real cost of labour prompted quick reaction by capital. From 1977 real wages gains were frozen. The rate of profit continued to fall in all regions until 1982 as rates of exploitation declined further and as the VCC and turnover times continued to rise.

The history of different regional manufacturers indicates that there was little possibility of escaping the crisis. In the Prairies, the pace of technical change was relatively slow and thus the value rate of profit did not decline as quickly as in other regions. However, the failure to innovate as rapidly as firms in other regions undermined the ability of Prairie manufacturers to compete in the market. The post-war history of manufacturing in Alberta was quite different. Rapid technical change, especially toward the end of the period, caused the value rate of profit to fall faster than in any other region. However, it appears that superior technology allowed Albertan firms to boost profits in the market. This was not sufficient to prevent the price rate of profit from falling though. Ontario and Quebec performed better than all other regions between 1955 and 1984. In both these regions the pace of technical change was below average and thus the value rate of profit fell more slowly than average. These regions did not perform very badly in the market however. While manufacturers in Ontario gained profits in the market, in Quebec, manufacturers lost profits but not at the same rate as the Prairies or the Atlantic region. The Atlantic provinces fared badly in both the market and in production. Rapid increases in the VCC through the 1960s severely reduced the value rate of profit. These techological advances did little however to improve the competitiveness of the Atlantic region which consistently performed very poorly in the market.

7.3.3 Regional Growth and Profitability: Convergence or Divergence

Received theory in regional economic analysis asserts that regional profit and growth rates tend towards an equilibrium characterised by the equality of both rates across space (Borts and Stein, 1964; Romans, 1965 and Siebert, 1969). While neoclassical theory provides an explicit mechanism for the spatial allocation of capital and labour in perfect markets, Marxist theory too, in the form of unequal exchange asserts that capital will flow between sectors of production tending to equalise the rate of profit. The lack of capital and profit data, especially at the regional level, means that empirical tests of these claims are rare. It remains an open question therefore, what patterns of development we are seeking to explain. For example, do regional profit and growth rates converge or not? This question is addressed in this section where the patterns of regional growth and profit rate variations in Canadian manufacturing are examined between 1955 and 1984.

Table 7.6 presents the results of a study of regional profit rate deviations in Canadian manufacturing. The data for this analysis are time series of regional profit rate deviations from the Canadian average. Inspection of the autocorrelation functions for the individual time series revealed that the deviation series exhibited a significant lag of the first order. Furthermore, on initial inspection, the time series appeared to be stationary. To examine the time series of regional profit rate deviations in more detail a first order auto regressive model was estimated.

Table 7.6 shows the estimated coefficients of the first order autoregressive model for each region. In all regions the autoregressive equation was significant and positive at the 95% level. In addition, the

TABLE 7.6: AUTOREGRESSIVE MODEL OF REGIONAL PROFIT RATE DEVIATIONS FROM THE CANADIAN AVERAGE

$$Y_{(t)} = a + bY_{(t-1)} + e_{(t)}$$

REGION	EST a	t-score*	EST b	95% CI		CONV	a/(1-b)
ATLANTIC	-0.048	-2.20	0.692	0.404	0.980	YES	-0.156
QUEBEC	0.021	3.16	0.483	0.177	0.789	YES	0.040
ONTARIO	0.011	2.49	0.646	0.351	0.941	YES	0.031
PRAIRIES	-0.007	-1.41	0.702	0.446	0.958	YES	CDN MEAN
ALBERTA	-0.009	-1.19	0.883	0.717	1.049	NO	
BC	-0.011	-1.20	0.877	0.693	1.061	NO	

TABLE 7.7: AUTOREGRESSIVE MODEL OF REGIONAL GROWTH RATE DEVIATIONS FROM THE CANADIAN AVERAGE

$$Y_{(t)} = a + bY_{(t-1)} + e_{(t)}$$

REGION	EST a	t-score*	EST b	95% CI		CONV	a/(1-b)
ATLANTIC	0.003	0.65	0.820	0.594	1.046	NO	
QUEBEC	-0.001	-0.77	0.609	0.248	0.963	YES	CDN MEAN
ONTARIO	-0.003	-0.36	0.747	0.482	1.012	NO	
PRAIRIES	-0.002	-0.70	0.675	0.378	0.972	YES	CDN MEAN
ALBERTA	0.003	0.60	0.889	0.618	1.060	NO	
BC	-0.003	-1.01	0.655	0.365	0.965	YES	CDN MEAN

* TWO-TAILED CRITICAL VALUE OF t AT 95% IS 2.05

estimated sample slope coefficient was in the range of -1 to 1 in each region and this affirms the earlier claim that the deviation series are indeed stationary (see O'Donovan, 1983 and Nelson, 1973). For 4 of 6 regions the 95% confidence interval around the estimated slope coefficient did not include the value of unity and thus for these regions the profit rate deviation series converge at the given level of probability. If the estimated sample intercept is not significantly different from zero, then the convergent deviation series tend towards the Canadian profit rate series. Again at the 95% significance level, the deviation series converges to the Canadian average in only one region, the Prairies. In Ontario and Quebec, the profit rate deviation series converge to values a few percentage points above the Canadian mean. In the Atlantic provinces, the profit rate converges to a level approximately 15.6% lower than the mean profit rate in the Canadian manufacturing sector. In general these results do not support the arguments of the neoclassical, neo-Ricardian or Marxist schools that claim profit rates tend to equalise throughout all sectors of the economy.

Table 7.7 presents the results of a first order autoregressive model of regional growth rate deviation series. The data for this analysis are deviations of regional growth rate series from the average rate of growth of the Canadian manufacturing sector. The autoregressive equations are positive and significant in all regions. From Table 7.7, it may again be observed from the estimated slope parameters that the growth rate deviation series for all regions are stationary. In addition, 3 of the deviation series are convergent, those for Quebec, the Prairies and BC.

In these three cases the deviation series converge to the average rate of growth of the Canadian manufacturing sector. While the convergent series exhibit the properties predicted by neoclassical regional growth theory, the fact that only half the series are convergent at the given level of probability casts further doubt on the general claims of this body of theory. Only in the Prairie region do the profit and growth rate deviation series behave as theory would predict.

The results from Tables 7.6 and 7.7 together, raise a further interesting question. Why is it for instance, that in Quebec, where the profit rate in the manufacturing sector is consistently higher than the Canadian average, do capitalists appear to invest outside this region, shown by the average rate of growth of the capital inputs to production? Although the evidence here is limited, it would appear that not only are claims of regional equilibrium wrong, but existing theory cannot even predict the direction of capital flows between regions. Clearly, the processes of regional competition and development are not well understood.

7.4 Regional Variations in the Performance of the Canadian Food and Beverage Industry

It is commonly argued that economic performance varies over space as the distribution of manufacturing activities changes (Fuchs, 1962). This is to some extent true. In the Canadian context for example, the economic history of Alberta from the mid 1970s on, is dominated by the petroleum and coal products sector. However, appeal to industry mix provides little explanation for region specific patterns of growth and decline and simply raises the issue why certain industries are concentrated in particular areas. The aim of this section is to make a crude adjustment for industry mix and re-evaluate regional economic performance in Canada. The adjustment method adopted is simply to examine the performance of one industry across six regions. It is acknowledged that this procedure is not perfect, for sectoral variations exist within the food and beverage industry itself and these will show some degree of spatial differentiation. However, it is expected that sectoral performance within the food and beverage industry will exhibit more uniformity than that between all components of the manufacturing sector.

The analysis comprises two parts. Sections 7.4.1 and 7.4.2 follow the pattern of 7.3.1 and 7.3.2, examining the components of the rate of profit of the food and beverage industry and the relative contribution each makes to changes in that rate. Section 7.4.3 examines whether or not profit rates within one industry and one region show any greater tendency towards equilibrium than in manufacturing as a whole.

7.4.1 The Rate of Profit in the Canadian Food and Beverage Industry

In the following 6 subsections, the components of the rate of profit and their relative effects on the performance of the food and beverage industry are examined. Only the main findings, including the differences between these results and those for the manufacturing sector as a whole will be discussed. Data availability limits analysis to the period 1961-1984. This period was divided into three sub-periods, 1961-1973, 1973-1981 and 1981-1984, by examination of the profit and capacity utilisation rate series for the industry as a whole.

7.4.1.1 The Rate of Exploitation

It was argued in Chapter 3 that the unit value of labour-power is constant within a particular branch of the economy. Thus, the value rate of exploitation is constant in the food and beverage industry in a given year across all regions. The price paid for a unit of labour (the real wage) may vary between regions however, as manufacturers obtain labour inputs to production for prices which differ from their values. This is one more component of market based competition and another cause of the deviation of the value and price rates of profit.

The (value) rate of exploitation in the food and beverage industry in Canada as a whole is consistently greater than the same rate for the economy as a whole, though the difference between the two rates has narrowed between 1961 and 1984. In the food sector, the rate of exploitation has decreased by approximately 10.3% since 1961. This decline was concentrated in the period to 1976 after which time exploitation rates have risen (see Figure 7.13).

Table 7.8 shows that the rate of exploitation in the food and beverage industry decreased by almost 22 percentage points between 1961 and 1984. By far the largest reductions in this rate occurred before 1973, when real wages increased rapidly. After 1973, the annual rate of increase of real wages declined by about 50%. Coupled with technical changes that reduced the value of consumer goods, the decrease in the exploitation rate slowed. After 1981 the rate of exploitation in the food industry increased in line with most manufacturing sectors.

FIGURE 7.13: THE RATE OF EXPLOITATION
(FOOD AND BEVERAGE)

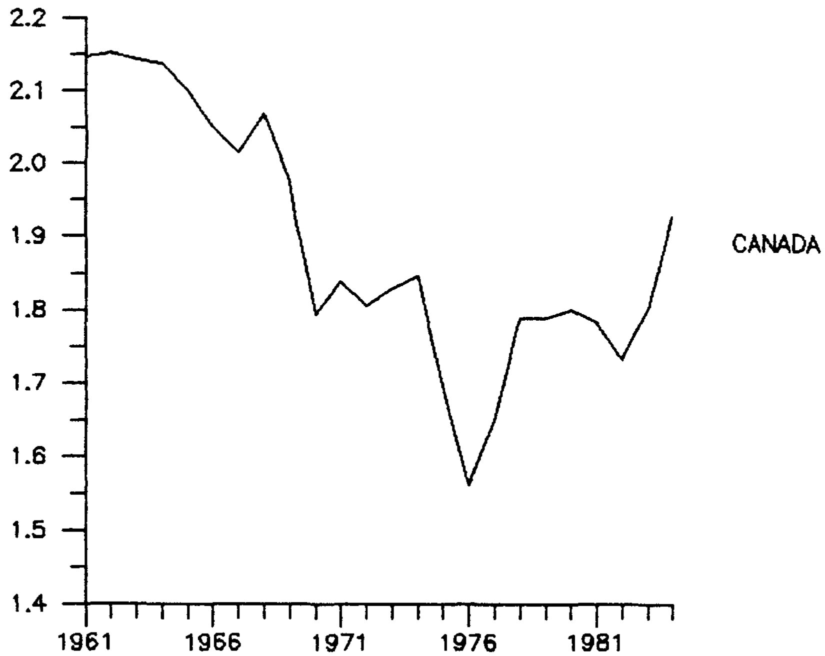


FIGURE 7.14: THE HOURLY REAL WAGE
(FOOD AND BEVERAGE)

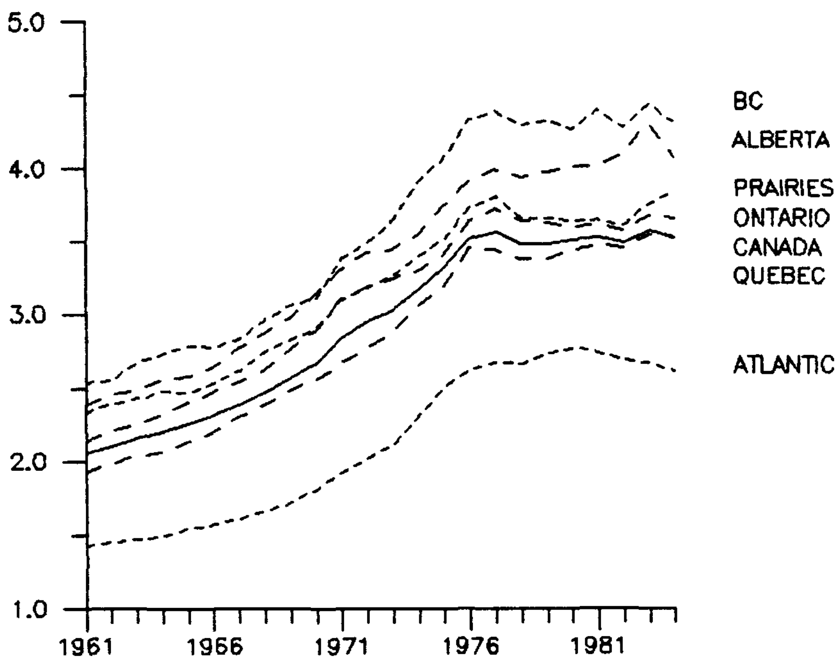


TABLE 7.8: DETERMINANTS OF THE RATE OF EXPLOITATION
(FOOD AND BEVERAGE)

PERIOD REGION	de	EFFECT OF THE VALUE OF CONSUMER GOODS	EFFECT OF THE REAL WAGE
1961-1973			
CANADA	-0.3172	0.8137	-1.1797
1973-1981			
CANADA	-0.0471	0.3609	-0.4408
1981-1984			
CANADA	0.1432	0.1328	0.0001

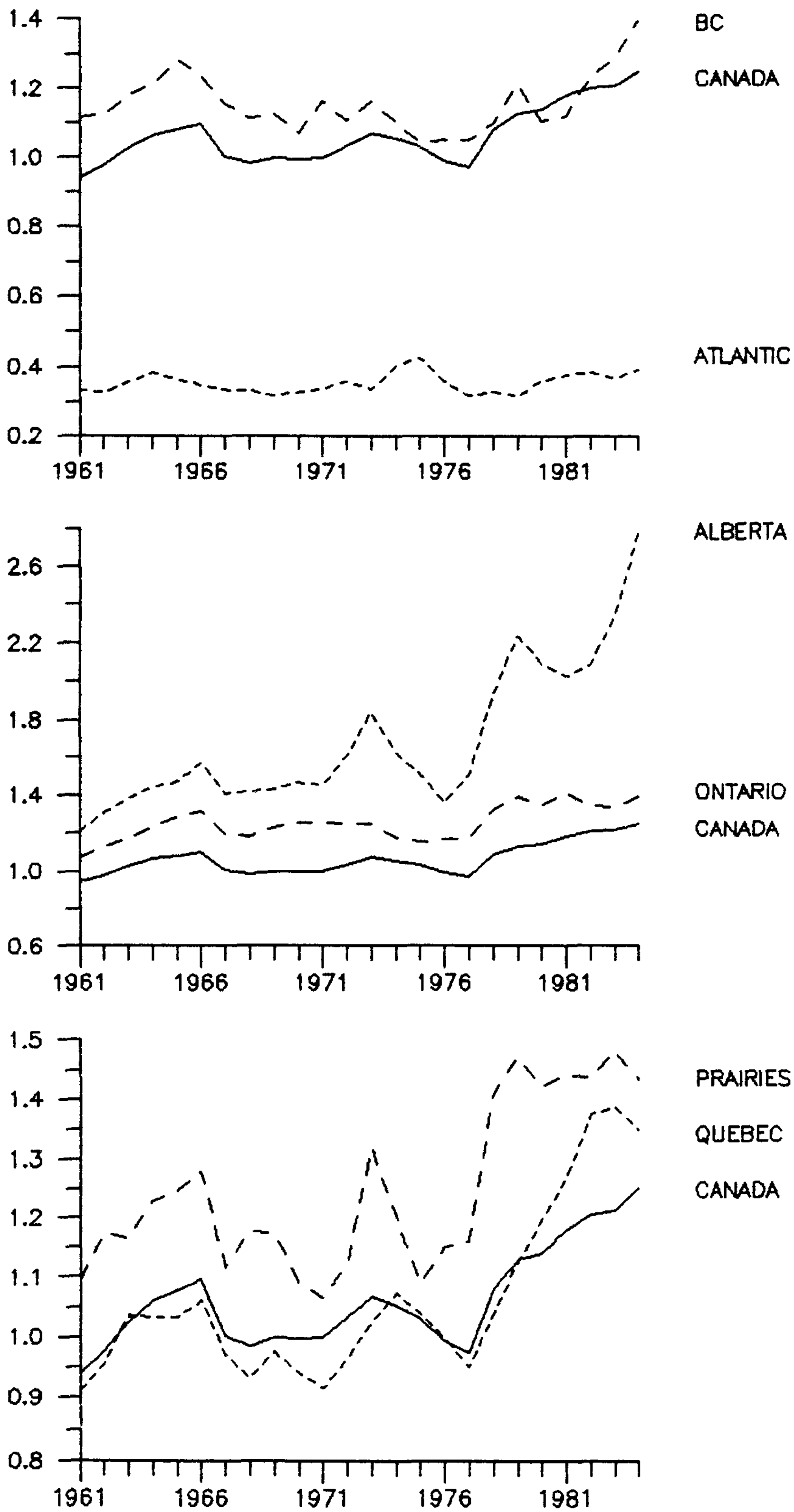
As the unit value of consumer goods is constant throughout the economy, variations in the (price) rate of exploitation are caused by sectoral and regional variations in the real wage. Figure 7.14 shows regional differences in hourly real wages in the food and beverage industry. In all regions between 1961 and 1984 the real wage increases. The rate of increase ranges from a low of 65% in the Prairies to a high of 83% in the Atlantic region and Quebec. The pattern of regional differences in wage levels in the food and beverage sector resembles closely that for manufacturing activities as a whole. Hourly real wages in the food industry tend to be a few percent lower than the manufacturing average, though in Quebec and in Alberta in 1984, they were slightly higher. The industry mix appears to explain little of regional wage differentials.

7.4.1.2 The Value Composition of Capital

The VCC increased on average by 33.1% in the food and beverage industry between 1961 and 1984 (see Figure 7.15). This average conceals wide variations in the pattern of change in the VCC across the six regions. In the Atlantic provinces for example, the VCC rose by only 18%, while in Alberta it increased by 130%. In Quebec, the VCC increased by just over 48% and in all other regions the rate of change of this variable was below the national average for the industry.

The absolute values of the VCC in the food industry and the regional patterns of its change are different from the manufacturing sector as a whole. For Canada in 1984, the VCC was approximately 50% larger in the food and beverage sector than the manufacturing average.

FIGURE 7.15: THE VALUE COMPOSITION OF CAPITAL (FOOD AND BEVERAGE)



The Canadian figure however hides different regional patterns. In the Atlantic region for instance, the VCC in the food and beverage industry in 1984 was only 25.4% of the average manufacturing VCC in this region. Similarly, the VCC in the food sector in Alberta was lower than average in manufacturing. In all other regions, the VCC in the food industry was greater than the manufacturing average. In terms of growth, the VCC in manufacturing industries as a whole increased approximately twice as quickly as in the food industry in all regions except the Atlantic provinces. In the latter area, the VCC in manufacturing in general increased over 15 times faster than in the food industry. In terms of timing too, the movement of the VCC in the food industry is somewhat different from the manufacturing aggregate, with increases in the VCC slowing down after 1981 in the Atlantic region, Quebec, Ontario and the Prairies.

Of the forces acting on the VCC, the TCC was dominant, overwhelming the combined effects of changes in the unit value of capital goods and the unit value of labour power up to 1981 in all six regions (see Table 7.9). In the Atlantic, Quebec, Ontario and Prairie regions, the effect of increases in the TCC were relatively stable up to the later 1970s, since which time they declined in importance in Ontario and the Prairies and increased in importance in Quebec and the Atlantic region. In BC, the TCC increased more rapidly after 1981 and was relatively constant throughout the 1970s. The food and beverage sector in Alberta behaves similarly to the manufacturing sector in general.

The relative effects of changes in the value of commodities has had a greater impact on the VCC in the food industry than in

TABLE 7.9: DETERMINANTS OF THE VALUE COMPOSITION OF CAPITAL (FOOD AND BEVERAGE)

PERIOD REGION	dq	EFFECT OF THE VALUE OF CAPITAL GOODS	EFFECT OF THE TECHNICAL COMPOSITION OF CAPITAL	EFFECT OF THE VALUE OF LABOUR POWER
1961-1973				
CANADA	4.3567	-9.6044	18.3170	-3.7775
ATLANTIC	0.0640	-3.2009	4.6899	-1.2371
QUEBEC	3.8895	-9.0668	17.1790	-3.6490
ONTARIO	5.9619	-11.6970	22.8310	-4.5690
PRAIRIES	7.5646	-10.6480	23.5340	-4.4960
ALBERTA	21.3621	-13.9950	42.0342	-5.2983
BC	1.6204	-10.7440	17.3060	-4.3499
1973-1981				
CANADA	3.7590	-2.6029	7.0938	-0.9377
ATLANTIC	1.3296	-0.8771	2.6772	-0.5457
QUEBEC	8.1433	-2.5948	11.6050	-1.0453
ONTARIO	5.6936	-3.0724	9.4334	-0.8240
PRAIRIES	4.0533	-3.0533	7.5966	-0.7901
ALBERTA	6.2937	-3.9902	10.5700	-1.4273
BC	-1.3380	-2.7731	2.0725	-0.8167
1981-1984				
CANADA	2.3961	-3.8031	4.4398	2.0107
ATLANTIC	0.6216	-1.1596	1.2740	0.6161
QUEBEC	2.7571	-4.3564	4.9510	2.3462
ONTARIO	-0.8704	-4.1839	1.4079	2.1567
PRAIRIES	-0.2727	-4.6359	2.0400	2.4262
ALBERTA	25.5548	-7.3058	30.025	3.8348
BC	9.2959	-4.0613	11.559	2.1866

manufacturing in general as the pace of increases in the TCC is less rapid in this sector. In all regions, over all periods, technical change reduced the value of capital goods and this tended to supress the rise in the VCC. In addition, between 1961 and 1981, the value of labour-power increased and this effect tended to work in concert with the falling value of capital goods and dampen the effects of the rising TCC on the VCC. After 1981, the value of labour-power fell in the food industry and this contributed to the increase in the VCC in four of the regions examined. In the Prairies and Ontario after 1981, reductions in the unit value of capital goods were sufficiently strong to overwhelm the effects of the rising TCC and the reduction in the value of labour power, and consequently the VCC fell.

7.4.1.2.1 The Technical Composition of Capital

In the food and beverage industry, the TCC increased on average by 128% between 1961 and 1984, about 50% of the increase in the manufacturing sector in general. The lowest rate of increase was in Ontario (93.1%) and the highest rate was in Alberta (295%). In all other regions, the rise in the TCC was closer to the industry average (see Figure 7.16 and Table 7.10). The timing of changes in the TCC in the food industry was quite different from manufacturing in general in all regions save Alberta and BC, with the TCC increasing strongly through the 1960s as well as after 1981.

For the most part, in all regions, changes in all four components of the TCC exerted a significant impact. In contrast to the manufacturing sector as a whole, changes in capacity utilisation rates,

FIGURE 7.16: THE TECHNICAL COMPOSITION OF CAPITAL (FOOD AND BEVERAGE)

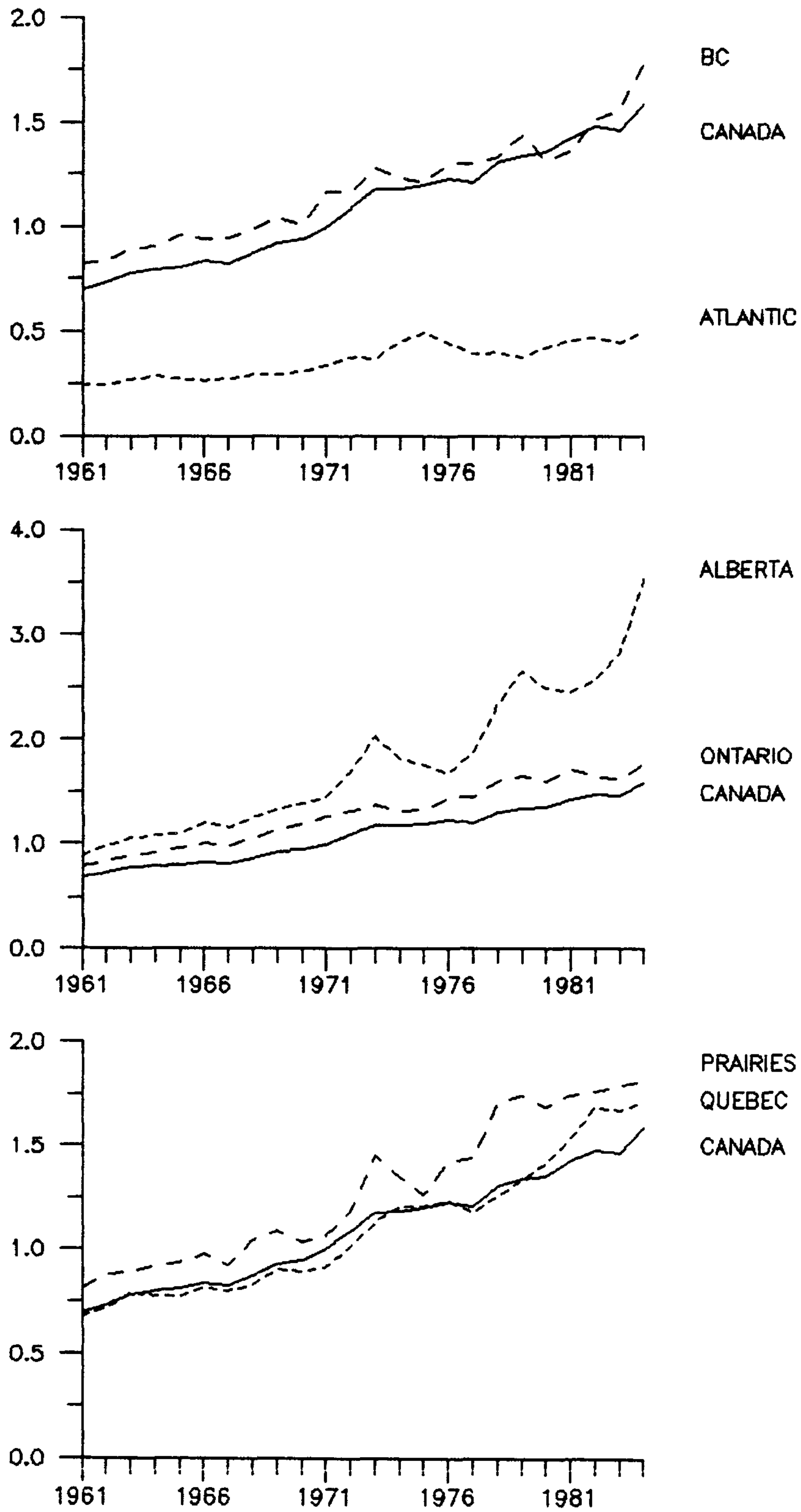


TABLE 7.10: DETERMINANTS OF THE TECHNICAL COMPOSITION OF CAPITAL (FOOD AND BEVERAGE)

PERIOD / REGION	dP	EFFECT OF TURNOVER TIMES	EFFECT OF CAPACITY UTILISATION	EFFECT OF TECHNICAL CHANGE	EFFECT OF LABOUR INTENSITY
1961-1973					
CANADA	46.8870	10.3140	-4.1692	29.5070	9.5756
ATLANTIC	11.7587	-0.3476	2.4592	6.1009	2.6828
QUEBEC	43.6770	10.5880	-5.4301	27.3370	10.0770
ONTARIO	55.7240	13.0000	-7.0180	38.3990	9.8899
PRAIRIES	61.5930	12.8620	-2.7279	35.1060	12.9900
ALBERTA	108.6650	35.7340	-23.0660	65.7130	25.8850
BC	43.6370	2.8980	5.1680	26.1780	7.1246
1973-1981					
CANADA	24.1400	6.1673	7.4173	6.3281	2.4209
ATLANTIC	8.0956	2.1450	2.5323	0.3420	1.2968
QUEBEC	38.7640	12.5540	6.7836	12.7100	4.6436
ONTARIO	32.6690	9.7837	5.0472	10.4260	3.5660
PRAIRIES	27.7870	-7.9482	27.6850	0.9780	-0.8557
ALBERTA	40.9660	-10.2860	30.8120	5.6512	0.3743
BC	7.5910	-2.9880	9.3663	-2.9733	-0.1566
1981-1984					
CANADA	15.2120	0.5706	7.6645	6.1251	0.4884
ATLANTIC	4.3310	-1.1386	4.0795	1.2822	-0.3112
QUEBEC	16.9960	2.523	5.1547	7.4066	1.2161
ONTARIO	4.7560	-4.8224	6.8362	3.0876	-0.8365
PRAIRIES	7.0410	5.5457	-12.1440	11.5780	1.8117
ALBERTA	103.4030	19.9080	38.4590	30.6940	6.0584
BC	39.7590	8.1600	9.9585	17.0350	2.4976

turnover times and labour intensity, exerted a greater influence on the TCC after 1973 than changes in the full capacity fixed capital to labour ratio. Between 1961 and 1984, technical change in the form of increases in the capacity adjusted fixed capital to labour ratio have been significantly slower than average in the food industry.

Capacity utilisation levels have generally been higher in the food and beverage industry than in the manufacturing sector as a whole (see Figure 7.17). In most regions, capacity utilisation rates declined through the 1960s contributing to the marked rise in the TCC. This pattern was consistent with general manufacturing trends. On the whole, fluctuations in capacity utilisation rates were less severe in the food industry than in general manufacturing. The same is true of variations in turnover times. Thus, the food and beverage industry appears less susceptible to business cycle fluctuations than most manufacturing industries.

7.4.1.3 The Turnover Time of Capital

Figure 7.18 shows how the number of turnovers (the inverse of the turnover time) has increased in the food and beverage industry between 1961 and 1984. On average across all regions, the number of turnovers in the food and beverage industry has risen by 27% since 1961. Alberta registered the largest increase in the speed of production, with the number of turnovers per annum rising by almost 66% between 1961 and 1984. In Quebec, the speed of production rose by 42%, while in BC and the Atlantic region, the speed of production increased by only 11.5% and 7.5% respectively. Ontario and the Prairies performed close to the

FIGURE 7.17: THE CAPACITY UTILISATION RATE
(FOOD AND BEVERAGE)

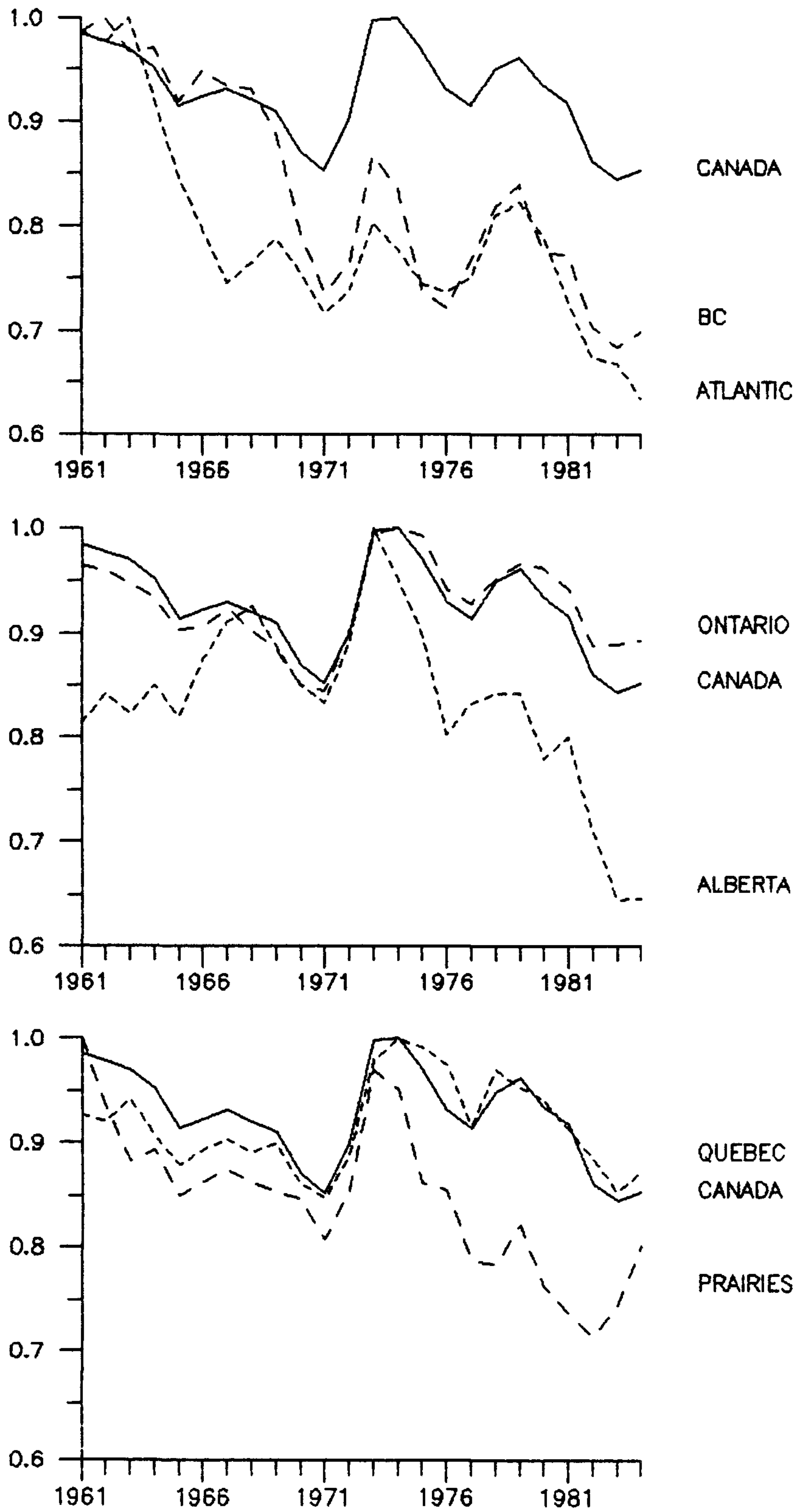
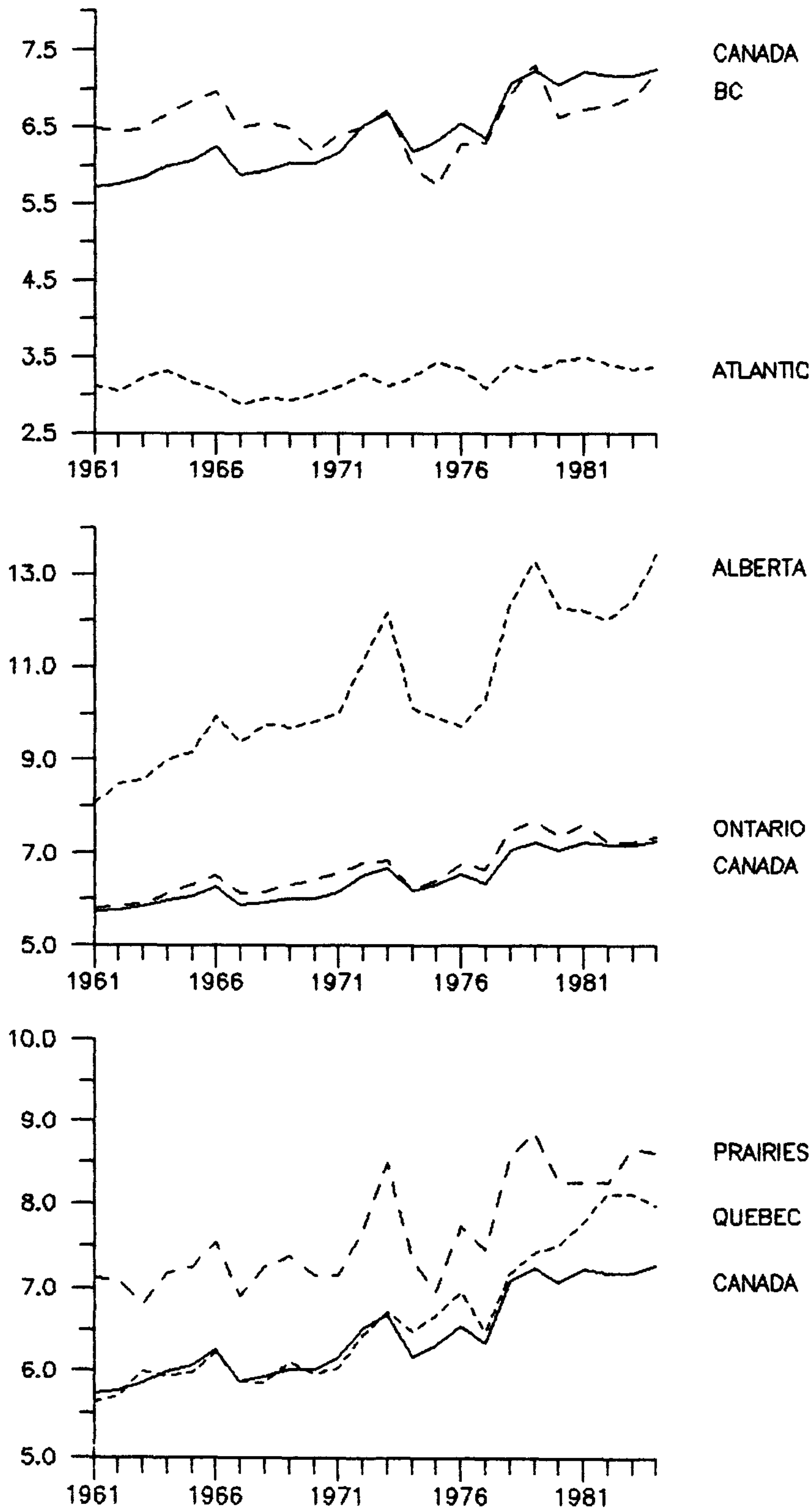


FIGURE 7.18: THE ANNUAL NUMBER OF TURNOVERS (FOOD AND BEVERAGE)



Canadian average for this sector.

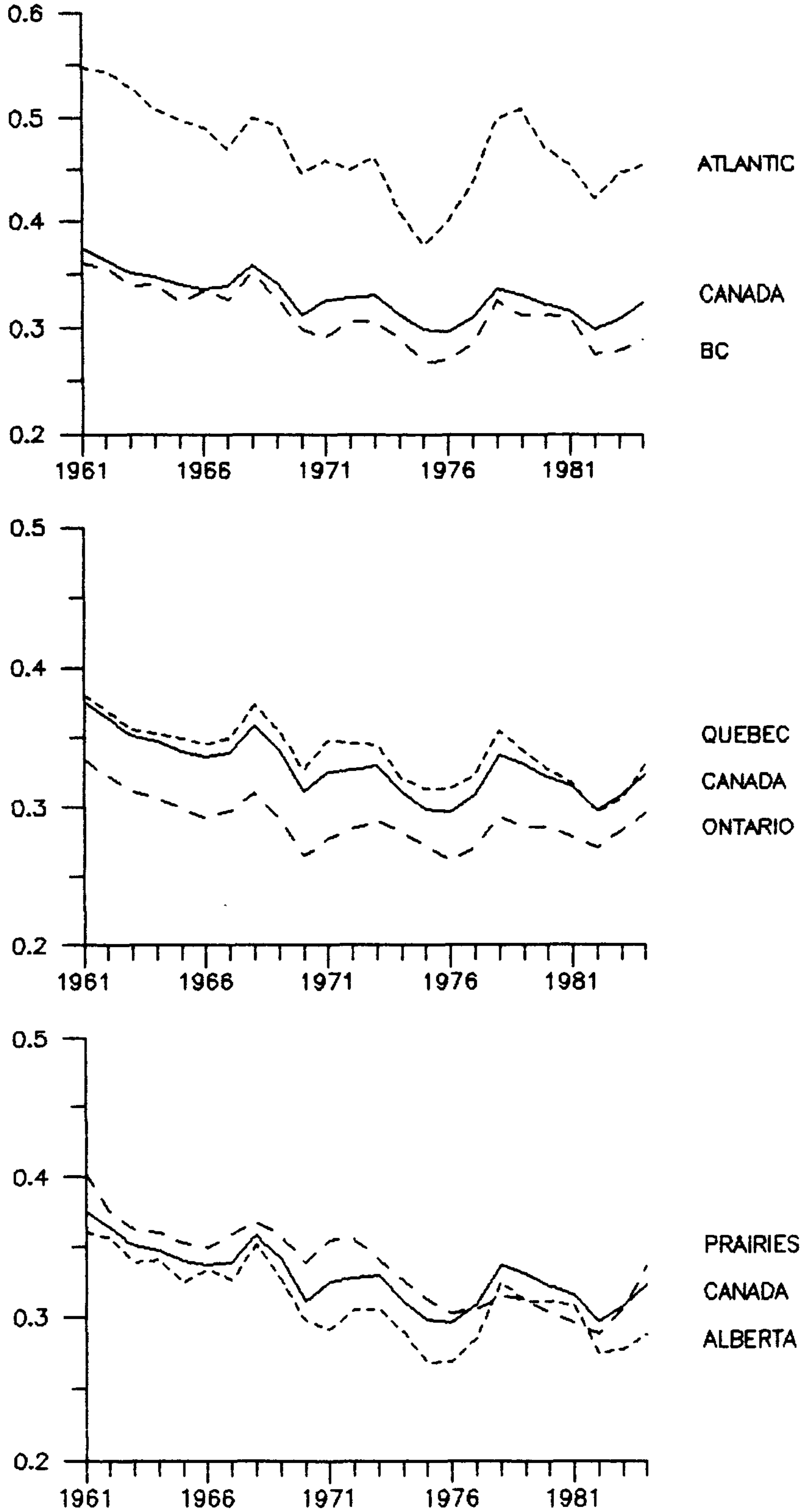
The speed of production in the manufacturing economy in general increased by almost 32% between 1955 and 1984. Thus, in terms of turnover times, at least for Canada as a whole, the performance of the food and beverage sector was on par with the industry average. Once more however, regional variations in performance within the food industry are marked and not entirely consistent with those same variations for the all industry aggregate. In the Atlantic provinces, whereas manufacturers in general managed to increase the annual number of turnovers by about 68%, in the food industry, the number of turnovers increased by only 7.5%. The food and beverage industry in the three western regions also performed relatively poorly in increasing the speed of production relative to the manufacturing average.

7.4.1.4 The Value Rate of Profit

Figure 7.19 shows regional variations in the value rate of profit in the food and beverage industry over the period 1961 to 1984. The value rate of profit is the synthesis of the variables discussed above. The value rate of profit in the food industry decreased in all regions. Ontario performed most efficiently, suffering a reduction in profitability of only 11.6%. Quebec was the only other region to perform better than the Canadian average in the food and beverage sector. The reduction in profitability was greatest in Alberta where the rate of profit declined from 41.5% in 1961 to 27.1% in 1984.

The value rate of profit was highest in the Atlantic region throughout the period. In 1984, the value rate of profit in the food and

FIGURE 7.19: THE VALUE RATE OF PROFIT (FOOD AND BEVERAGE)



beverage industry in this region was 45.4%. In contrast, the average value rate of profit in the food and beverage industry in 1984 was 32.4%. The Prairies and Ontario register the lowest value rate of profit in the food industry, with values of 27.1% and 29.6% respectively in the same year.

In 1984, the value rate of profit in the food and beverage industry was slightly higher than the average rate for all manufacturing activities. This result holds for three of the six individual regions, but in Quebec, Ontario and the Prairie provinces the rate of profit in the food sector was below the manufacturing average, largely because the VCC in the food sector was higher than the manufacturing average in these regions. The pattern of relative performance levels between the food and beverage industry and the manufacturing sector as a whole is quite uneven over the study period within regions, though in general, the decline in the value rate of profit has been slower in the food industry. For Canada as a whole, the value rate of profit in the food and beverage sector was lower than the manufacturing average until the late 1970s since which time it has been greater.

Table 7.11 shows that in the food sector, just as manufacturing in general, the VCC was chiefly responsible for the decline in the value rate of profit. However, the increase in the VCC has exerted a smaller impact in the food industry, largely because the pace of technical change was slower than average in this sector. This finding is consistent across all regions, although regional differences in the effect of increases in the VCC on the rate of profit are considerable even in the food industry. With the exception of the Atlantic provinces, these

TABLE 7.11: DETERMINANTS OF THE VALUE RATE OF PROFIT (FOOD AND BEVERAGE)

PERIOD / REGION	$d\pi_v$	EFFECT OF THE RATE OF EXPLOITATION	EFFECT OF THE VALUE COMPOSITION OF CAPITAL	EFFECT OF TURNOVER TIMES
1961-1973				
CANADA	-0.0454	-0.0537	-0.0478	0.0510
ATLANTIC	-0.0847	-0.0780	-0.0131	-0.0067
QUEBEC	-0.0348	-0.0557	-0.0501	0.0618
ONTARIO	-0.0443	-0.0464	-0.0522	0.0486
PRAIRIES	-0.0610	-0.0554	-0.0800	0.0574
ALBERTA	-0.0631	-0.0610	-0.1698	0.1476
BC	-0.0539	-0.0519	-0.0190	0.0081
1973-1981				
CANADA	-0.0144	-0.0043	-0.0345	0.1940
ATLANTIC	-0.0080	-0.0009	-0.0885	0.0497
QUEBEC	-0.0283	-0.0039	-0.0769	0.0447
ONTARIO	-0.0125	-0.0052	-0.0522	0.0486
PRAIRIES	-0.0445	-0.0062	-0.0311	-0.0241
ALBERTA	-0.0390	-0.0049	-0.0518	-0.0157
BC	0.0030	-0.0039	0.0154	-0.0107
1981-1984				
CANADA	0.0080	0.0243	-0.0179	0.0014
ATLANTIC	-0.0017	0.0348	-0.0222	-0.0158
QUEBEC	0.0133	0.0240	-0.0206	0.0078
ONTARIO	0.0176	0.0225	0.0042	-0.0097
PRAIRIES	0.0394	0.0243	0.0019	0.0117
ALBERTA	-0.0413	0.0221	-0.0963	0.0252
BC	-0.0206	0.0214	-0.0648	0.0187

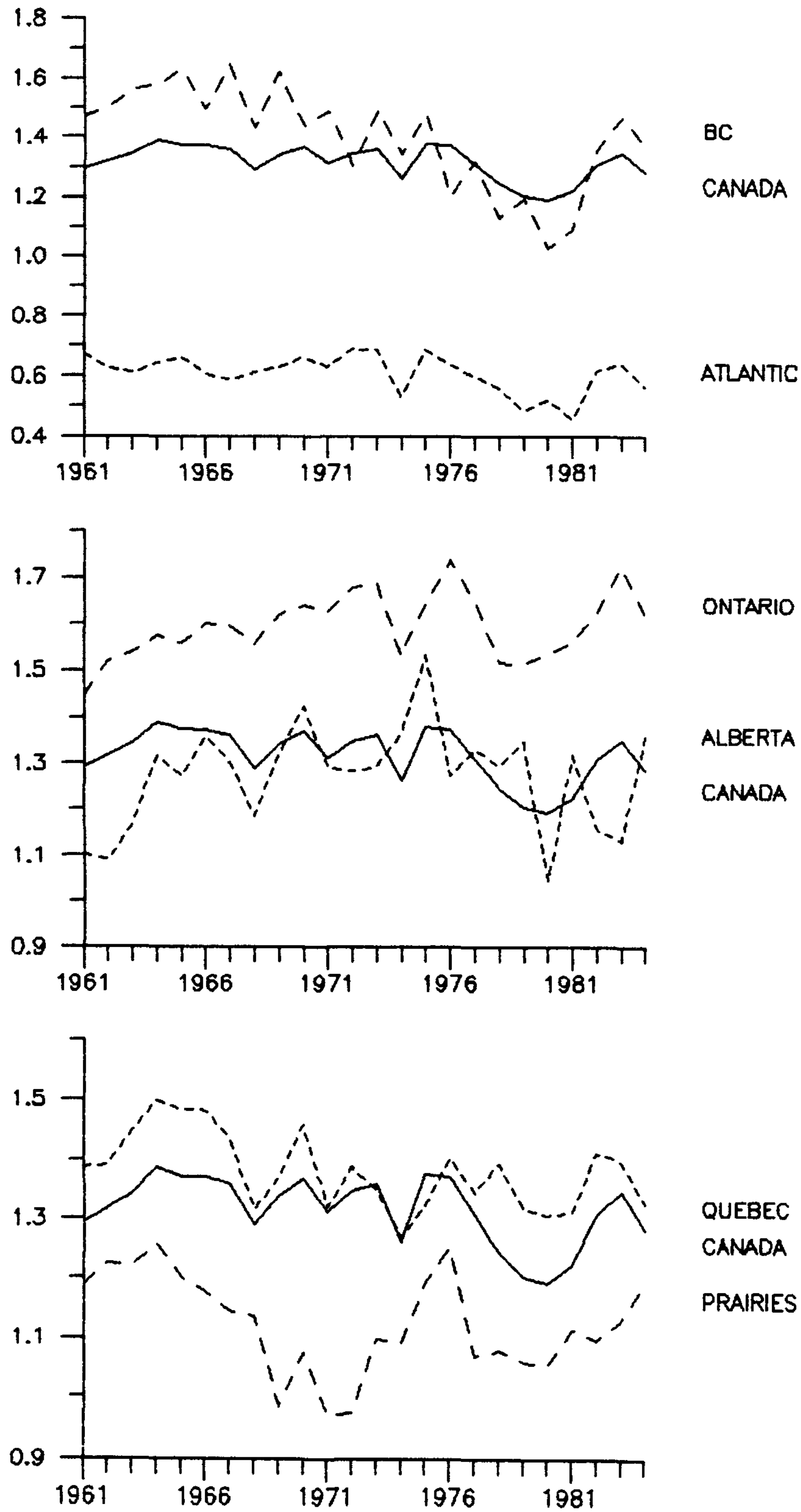
regional variations are consistent with the aggregate manufacturing data.

Between 1961 and 1984 reductions in the rate of exploitation contributed to the fall in profitability. This trend is also consistent with the manufacturing sector as a whole and affirms the earlier finding that the rate of exploitation has not been a significant counter-tendency to the fall in the rate of profit in post-war Canada. Reductions in the turnover time of capital in the food industry have had a positive impact on the rate of profit. Furthermore, this impact has been more consistent in the food industry than manufacturing in general, as cyclical fluctuations in turnover times in the food industry were relatively minor.

7.4.1.5 Price-Value Deviations

Figure 7.20, shows that firms in the food and beverage sector have performed relatively efficiently in the market, on average between 1961 and 1984, raising their price rate of profit by almost 30% over their value rate. The food and beverage industry captured most profit in the market in the mid-1960s, since which time the price-value deviation has slowly, though not consistently, decreased. These results accord with those of Webber and Tonkin (1987). In all regions, the food and beverage sector has outperformed the manufacturing aggregate in this measure of performance. Nonetheless, regional variations in the ability of food and beverage producers to acquire surplus in the market varies in a fashion similar to that for the manufacturing sector as a whole. The Atlantic region is the only area in which the food and beverage industry loses surplus in the market, though it does perform slightly better than

FIGURE 7.20: THE PRICE-VALUE DEVIATION
(FOOD AND BEVERAGE)



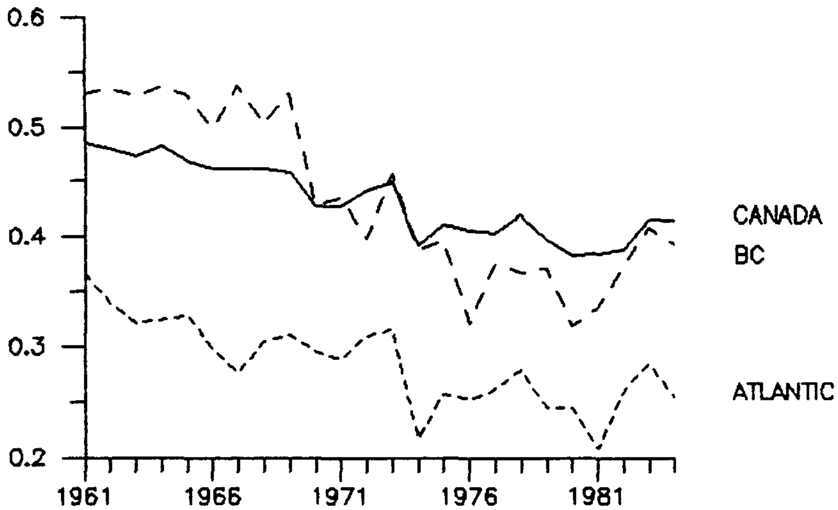
the manufacturing average. In all other regions, including Quebec and the Prairies which are net losers in the market at the level of manufacturing in general, firms in the food and beverage sector capture profits in the market, either from other industries in the same region, or from the same industry or different industries in other areas.

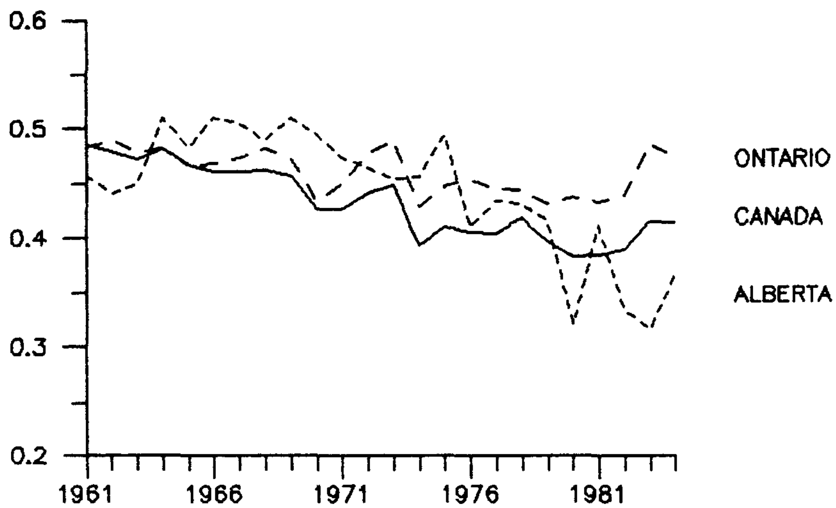
7.4.2 The Price Rate of Profit

The price rate of profit in the food and beverage industry decreased between 1961 and 1984 in all regions (see Figure 7.21). This reduction in profitability was relatively constant until 1981 since when the rate of profit increased slightly in all regions except Alberta. Across Canada, the reduction in profitability in the food industry has been less severe than in the manufacturing sector as a whole. Furthermore, in all regions in 1984 the rate of profit in the food industry was greater than the manufacturing average. In fact, in Alberta, BC and the Atlantic regions in 1984, the rate of profit in the food and beverage industry was more than twice that of manufacturing in general.

Table 7.12 shows the relative effects of production and market efficiency on the price rate of profit in the food industry. Though firms in this industry generally capture profit in the market, their ability to do so diminished in Quebec and BC, especially in the 1970s. In Ontario, Alberta and to a lesser extent the Prairies, firms in the food and beverage industry have become more competitive in the market. These changes are not similar to the experience of manufacturers in general in these regions.

FIGURE 7.21: THE PRICE RATE OF PROFIT (FOOD AND BEVERAGE)





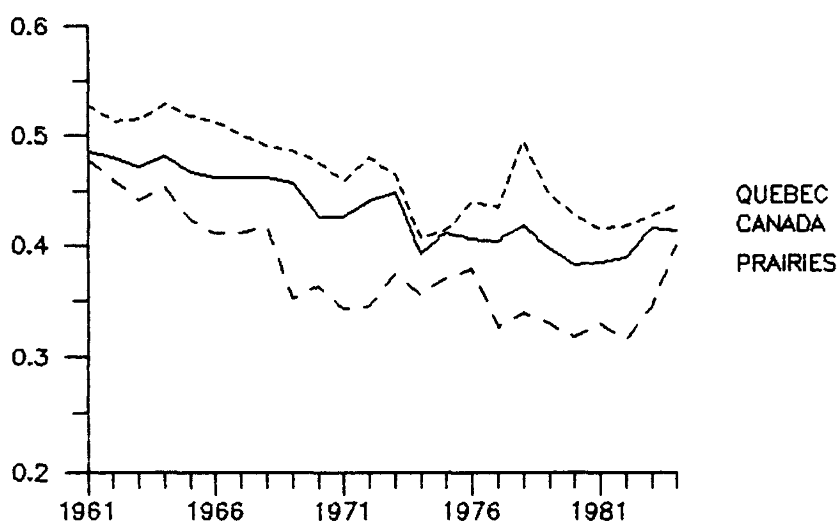


TABLE 7.12: DETERMINANTS OF THE PRICE RATE OF PROFIT (FOOD AND BEVERAGE)

PERIOD / REGION	$d\pi_p$	EFFECT OF PRICE-VALUE DEVIATION	EFFECT OF VALUE RATE OF PROFIT
1961-1973			
CANADA	-0.0370	0.0263	-0.0588
ATLANTIC	-0.0506	0.0037	-0.0528
QUEBEC	-0.0615	-0.0068	-0.0444
ONTARIO	0.0055	0.0748	-0.0659
PRAIRIES	-0.1037	-0.0306	-0.0684
ALBERTA	-0.0034	0.0820	-0.0707
BC	-0.0735	0.0173	-0.0787
1973-1981			
CANADA	-0.0635	-0.0449	-0.0165
ATLANTIC	-0.1084	-0.1071	0.0012
QUEBEC	-0.0501	-0.0169	-0.0370
ONTARIO	-0.0567	-0.0350	-0.0172
PRAIRIES	-0.0442	0.0070	-0.0486
ALBERTA	-0.0870	0.0113	-0.0526
BC	-0.1204	-0.1150	0.0020
1981-1984			
CANADA	0.0294	0.0189	0.0126
ATLANTIC	0.0471	0.0476	0.0047
QUEBEC	0.0214	0.0048	0.0205
ONTARIO	0.0424	0.0128	0.0303
PRAIRIES	0.0699	0.0233	0.0440
ALBERTA	-0.0438	0.0053	-0.0511
BC	0.0568	0.0844	-0.0176

In all regions except the Atlantic provinces and Ontario, the history of the price rate of profit was dominated by changes in the value rate. Reductions in the value rate of profit in all regions tended to depress the price rate of profit, though not to the same extent as in manufacturing as a whole. Food and beverage producers performed better than most manufacturers in production because the VCC increased relatively slowly in this sector. In turn, the slow rate of growth of the VCC resulted from a lower than average rate of technical change and above average rates of capacity utilisation. The sluggish rate of technical progress in the food industry did not hamper the market performance of this sector however. This is largely because the food and beverage sector is more capital intensive than manufacturing industries in general.

Ontario performed significantly better than any other region between 1961 and 1984, its rate of profit falling by less than 2%. Quebec, the Prairies and Alberta all suffered a reduction in the rate of profit of about 18% over the same period. In BC the profit rate fell by nearly 26%. The Atlantic region again performed worst, its rate of profit falling by just over 30%.

In all regions, the value rate of profit declined faster than the price rate indicating some degree of market edge in this sector. Ontario outperformed all other regions in the market. This was not the only cause of the relatively strong performance of this region however, for technical change and thus reductions in the value rate of profit were also slower in Ontario than elsewhere. In contrast, the Atlantic was the only region to lose surplus in the market in the food and beverage industry. This was the primary cause of this region's relatively poor economic record, especially since the mid-1970s. In fact, if food and beverage manufacturers had been able to retain their profit in the market, the Atlantic region would have been by far the most profitable in this sector over the entire post-war period. In Alberta, the rapid pace of technical change depressed the value rate of profit, much like the manufacturing sector as a whole in this region, but increased market efficiency countered the reduction in profitability to some extent. In BC, market performance deteriorated as the value rate of profit fell, contributing to the second worst post-war record in the food industry. The food and beverage industry in Quebec and the Prairies shared a similar history with a gradual decline in the value rate of profit and little change in market performance.

7.4.3 Regional Profitability and Growth in the Food and Beverage Industry

Table 7.6 showed little support for the argument that regional manufacturing profit rates tend to converge to the national average. This may be the result of either sectoral or spatial barriers which impede the flow of information or the equilibrating flows of capital. These claims are examined in Tables 7.13 and 7.14. These tables follow the same format as those presented in Section 7.3.3.

Table 7.13 examines regional profit rate deviations from the Canadian average in the food and beverage industry. If sectoral barriers prevent the equalisation of profits, then it is expected that within one industry there should be a greater tendency for regional profit rates to

TABLE 7.13: AUTOREGRESSIVE MODEL OF REGIONAL PROFIT RATE DEVIATIONS FROM THE CANADIAN AVERAGE IN THE FOOD AND BEVERAGE INDUSTRY

$$Y_{(t)} = a + bY_{(t-1)} + e_{(t)}$$

REGION	EST a	t-score*	EST b	95% CI		CONV	a/(1-b)
ATLANTIC	0.137	4.51	0.083	-0.765	0.932	YES	0.149
QUEBEC	-0.019	-2.47	0.445	0.034	0.856	YES	-0.034
ONTARIO	-0.006	-1.65	0.882	0.661	1.103	NO	
PRAIRIES	0.033	2.77	0.425	0.027	0.823	YES	-0.057
ALBERTA	-0.005	-0.58	0.542	0.151	0.932	YES	-0.011
BC	0.011	0.17	0.713	0.403	1.023	NO	

TABLE 7.14: AUTOREGRESSIVE MODEL OF PROFIT RATE DEVIATIONS IN THE FOOD AND BEVERAGE INDUSTRY FROM THE REGIONAL AVERAGE

$$Y_{(t)} = a + bY_{(t-1)} + e_{(t)}$$

REGION	EST a	t-score*	EST b	95% CI		CONV	a/(1-b)
ATLANTIC	0.0003	0.02	0.404	-0.432	1.241	NO	
QUEBEC	-0.070	-3.24	0.304	-0.116	0.724	YES	-0.101
ONTARIO	-0.031	-1.79	0.712	0.385	1.039	NO	
PRAIRIES	-0.247	-1.91	0.625	0.299	0.951	YES	REGIONAL MEAN
ALBERTA	-0.170	-4.09	0.076	-0.386	0.538	YES	-0.184
BC	-0.030	-1.27	0.826	0.597	1.055	NO	

* TWO-TAILED CRITICAL VALUE OF t AT 95% IS 2.07

converge. The results in Table 7.13 show that this is not the case. Though the regional profit rate deviation series converged in 4 regions, in none of these cases did the series converge to the Canadian average.

Table 7.14 examines the tendency for manufacturing profit rates to converge at the regional level. If firms in one region do not compete in national markets then there would be little chance of profit rate equalisation in distant markets. Examination of a regional market to some extent removes the spatial barriers preventing profit rate equalisation. The data in this table are deviations of the profit rate in the food and beverage industry from the manufacturing average in each region. Again, the results in Table 7.14 provide scant evidence to support the convergence hypothesis.

7.5 Conclusion

This chapter examined the determinants of the rate of profit in the food and beverage industry and in manufacturing in general in 6 regions over the post-war period. The rate of profit declined in all regions in the food industry and in manufacturing as a whole. The data does not indicate that a sudden downturn in profitability followed a period of stable and relatively high profits. Rather, the rate of profit declined consistently though somewhat faster during the business cycle downturns of the late-1950s and the late-1970s.

The empirical work confirms the theoretical arguments of Chapter 5, that labour-saving technical change causes the rate of profit to fall. It thus provides strong support for the Marxist theory of the falling rate of profit. Rising wage bills throughout the manufacturing sector prompted the introduction of labour-saving technical changes, but these only compounded the pressure on the rate of profit. The data also suggest certain modifications to the Marxist model. In particular, it was found that increases in the rate of exploitation were not a significant counter-tendency to the falling rate of profit. Reductions in the turnover time of capital were shown to have had the strongest positive effect on the rate of profit.

Examination of the food and beverage industry revealed that manufacturing fortunes are likely to differ substantially between industries. The rate of profit in the food industry in 1984 was more than twice that in manufacturing as a whole in Alberta, BC and the Atlantic region. In all other regions too, profitability in the food sector was significantly higher than average. In general therefore, it is not possible to infer the extent of the crisis in manufacturing from an examination of aggregate data alone.

Regional variations in economic performance were also marked. In 1984, manufacturing profit rates in Ontario and Quebec were well over twice those in the Atlantic region. The proponents of the industry mix argument assert that economic performance within an industry will be relatively similar across space and that regional variations in growth result from differences in industrial composition. The empirical work flatly refutes this thesis. Apart from the positions of Ontario and Quebec, a ranking of regions by profit rates produces the same order for manufacturing in general and for the food and beverage industry. Significant regional variations in performance were observed in the food and beverage industry. Thus, variations in rates of regional growth and decline must be sought in factors specific to certain places, rather than in factors specific to particular industries. Explaining regional fortunes thus demands examination of the history of development of particular regions, of the emergence of productive forces and the changing social relations between capital and labour and of political forces that influence these relations. The empirical work in this chapter is an integral part of such analysis, providing some clues as to why certain regions perform better or worse than others.

Finally, this chapter examined whether or not regional profit and growth rates tend to converge. Almost no evidence was found to support the convergence hypothesis at the level of manufacturing in general. Theoretical explanations for this "perverse" result stress the existence of sectoral and spatial barriers that restrict competition and inhibit equilibrating flows of capital. These claims were also tested by examining the tendency of profit rates to converge within one industry and within particular regions. The convergence hypothesis was not supported in either case. It appears that the notions of equilibrium or of competitive forces acting to enforce equilibrium have little foundation.

CHAPTER 8

CONCLUSION

The aims of this thesis were; firstly, to examine the internal consistency of the Marxist theory of the falling rate of profit; secondly, to use that theory to explain the post-war decline of the Canadian manufacturing sector; and thirdly, to gauge the sectoral and spatial extent of the manufacturing crisis in Canada. These tasks comprised the body of the thesis. Chapters 3 through 6 dealt with the theoretical issues and thus the first of the above aims. Chapter 7 tackled the second and third aims, documenting the post-war performance of the manufacturing sector in six Canadian regions. This chapter summarises the main findings of the research and suggests some avenues for future investigation.

Previous studies of Marxist economics, both theoretical and empirical, have been hindered by the restrictive conditions under which commodity values can be calculated, and by the transformation problem, the lack of a direct correspondence between the labour values of commodities and their respective prices. Chapter 3 provides an accounting framework that overcomes both of these shortcomings. First, it shows how commodity values can be calculated when fixed capital and variations in the rate of turnover of capital are not assumed away and when the production process is not point-input point-output. Second, Chapter 3 argues that competition does not necessarily move the economy towards an equilibrium state characterised by the equality of the rate of profit in all sectors of production. Thus, the transformation problem as traditionally conceived is misplaced. The neo-Ricardian claim that prices of production are the centres of gravity around which market prices fluctuate cannot be sustained theoretically or empirically. Market prices cannot be determined from commodity values or from the technical coefficients of production. Building on the work of Farjoun and Machover (1983), it is claimed that the chaos of the market means that the prices of commodities must be treated as random variables, determinate only up to a probability distribution. It is then shown that the expected price of a commodity is equal to its labour value. The labour theory of value is not therefore redundant as Steedman (1977) claims, in fact it is indispensible for estimating the expected prices of commodities and various measures of economic performance.

In Chapter 4, a Marxist model of accumulation in a two-commodity economy with no technical change is outlined. The growth model shares a number of characteristics with similar models of a neoclassical variety. For example, it is established that an equilibrium growth path for the Marxist model exists, that it is unique and stable. In addition, the equilibrium growth path in this economy is determined by the natural rate of growth of the labour force.

Examination of the properties of the growth model established that there is no systemic tendency for the rate of profit to fall. The Marxist theory of capitalist crisis is thus shown to depend on technical change. Unlike the neoclassical growth models, the Marxist variant shows that equilibrium does not demand that the rate of profit be equal throughout the economy, merely that it is unchanging through time. The conditions under which overproduction occurs are also shown in this simple model. If the economy shifts to a higher equilibrium growth path, the real wage falls, profits rise, and if the propensity to consume from profits remains constant, then the consumer goods department cannot sell all its output. Conversely, if the equilibrium growth rate falls, the real wage rises, profits fall and the capital goods department finds itself overproducing. Overproduction is shown to be short-lived however, as changes in the relative rates of profit in the two departments reallocate capital away from the sector that is overproducing.

The simple model outlined in Chapter 4 provides the basis for the analysis of the effects of technical changes upon the economy. Chapter 5 examines the impact of technical changes of various sorts on commodity values, expected prices and measures of economic performance. Technical change was defined simply as any alteration in the value of the aggregate capital or labour input coefficients. Three main results were found. Firstly, technical changes that increase the technical composition of capital do not necessarily increase the value composition of capital and thus exert a downward pressure on the rate of profit. Secondly, technical changes that cause the value composition of capital to rise are not always countered by increases in the rate of exploitation. These two arguments run counter to established claims in Marxist economic theory.

The third result of Chapter 5 and perhaps the most important finding of this thesis is that in an economy where real wages adjust to clear the consumer goods market, the introduction of viable labour-saving technical changes may cause the aggregate rate of profit to fall. This result effectively counters Okishio's (1961) damaging attack on the Marxist theory of the falling rate of profit. It does so without introducing any of the complexities of joint production or fixed capital, and shows simply that if the assumptions of a constant real wage and no realisation problems are stripped from Okishio's model then his theorem no longer obtains. Van Parijs (1980) provided an obituary for a "straw-man".

Overcoming the hurdle of Okishio's theorem means that the falling rate of profit theory can once more be set up as a logically consistent explanation of capitalist crisis. It still remains however, to establish why labour-saving technical changes would be introduced to the economy at a particular time rather than those of another type. This was the task of Chapter 6.

Chapter 6 critically reviews models of induced innovation, learning by doing and localised search for new techniques. These models were found wanting in a number of respects. A probabilistic model of the likely direction of technical change was advanced that overcomes some of the criticisms of the earlier work. In particular, it provides a clear definition of what constitutes technical change, it manages to capture the notion of localised search emanating from learning by doing and it does not rely on a purely random search process. The likely direction of technical change in this model is constrained by relative factor prices and is thus directed by conditions of production. The model predicts that increases in the relative price of one of the factors of production will lead to the adoption of a new technique that is biased towards saving on the input that has become relatively more expensive. This model provides the justification for the earlier claim that when the price of labour becomes relatively more expensive, firms will adopt new techniques of production that are labour-saving. Empirical tests using data from the Canadian food and beverage industry provided strong support for the model.

In Chapter 7, data from the Canadian manufacturing sector were used to measure various indicators of economic performance and examine the usefulness of the Marxist theory of the falling rate of profit as an explanation of economic decline. The data were also employed to examine the spatial extent of the manufacturing slowdown, to evaluate the competitive position of different regions in Canada and to reveal how "regions" compete with one another. Few, if any, previous studies have been able to calculate the rate of profit and its components at this level of detail. Until now this task has certainly not been performed on the Canadian economy.

In the Canadian manufacturing sector as a whole, the rate of profit declined in all regions between 1955 and 1984. The reduction in profitability was relatively consistent, although it accelerated somewhat during the business cycle downturns of the late-1950s and mid-1970s. The empirical analysis confirms the validity of the Marxist theory of the falling rate of profit and explanations of economic recession based on that theory. Up to the mid-1970s real wages increased rapidly, though they did not tend to lower the rate of profit for technical changes reduced the value of consumer goods and thus maintained the rate of exploitation. However, these same labour-saving technical changes exerted a profound negative effect on the rate of profit by increasing the value composition of capital. Contrary to received theory, the rate of exploitation did not act as a significant counter-tendency to the rise in the value composition of capital and thus the rate of profit fell. Reductions in the turnover time of capital were shown to have had the strongest positive impact on the rate of profit. The significance of this variable has traditionally been overlooked in Marxist empirical analysis.

Regional variations in the rate of profit and other measures of performance are significant. In 1984 for instance, the manufacturing rate of profit was more than twice as high in Ontario and Quebec as it was in the Atlantic region. Only Quebec and Ontario posted an average rate of profit between 1955 and 1984 that was greater than the national average. Over the thirty years, firms in the Atlantic region suffered the worst decline in performance, the rate of profit falling by nearly 61%. The reduction in profitability was also severe in Alberta (-50.2%), in the Prairies (-48%) and in British Columbia (-42%). Both Ontario and Quebec performed better than average, suffering a decline in profitability of only 28% and 35% respectively.

Two forms of competition are identified in this thesis; competition in production and competition in the market. Distinguishing between the two forms of competition proved very useful in interpreting regional variations in profitability. In the Prairies for example, poor market performance was the main cause of the reduction in the price rate of profit. The pace of technical change was slow in this region and thus the value rate of profit did not decline as quickly as elsewhere. However, the failure to innovate as rapidly as firms in other regions undermined the ability of Prairie manufacturers to compete in the market. In all other regions, reductions in the value rate of profit prompted by labour-saving technical changes and also by reductions in the capacity utilisation rate were the primary cause of declining profitability. In Alberta, BC and to a lesser extent Ontario, profits were captured from other regions in the market, but these were not sufficient to offset the decrease in the value rate of profit. Firms in Atlantic Canada and Quebec performed relatively poorly in the market.

At this aggregate level it is not possible to determine whether regional differences in profitability reflect the performance of manufacturing firms in general or whether they reflect regional variations in the distribution of industries. In addition, it is unclear whether the decline in the manufacturing rate of profit is dominated by a few sectors of production or if it is widespread. To examine these issues, the regional performance of the food and beverage industry was examined.

The price rate of profit in the food and beverage industry decreased between 1961 and 1984 in all regions. However, the reduction in profitability was much less severe than in manufacturing in general. In all regions in 1984, the rate of profit in the food and beverage industry was substantially higher than the manufacturing average. For the most part this reflects the ability of manufacturers in this industry to appropriate profit from other sectors in the market. It does not appear safe to infer the extent of the manufacturing crisis from an examination of aggregate data alone.

Regional differences in economic performance are also marked in the food industry. In general, those regions that posted a relatively high rate of profit in the food sector were also those in which the average manufacturing profit rate was relatively high. These results offer little support for the "industry-mix" explanation of regional performance. Variations in rates of regional profitability, growth and decline must be sought in factors specific to certain places rather then in factors specific to particular industries.

Finally, Chapter 7 examined whether or not regional profit and growth rates tend to converge as predicted by neoclassical economic theory. Empirical analysis flatly rejected the convergence hypothesis. Not only was there almost no evidence of convergence, but capital flows in one region moved in the opposite direction to that predicted by the neoclassical model. Further analysis, after adjusting for the possibility of sectoral and spatial barriers to the mobility of capital, did not alter the results.

This study examines the economic logic of the processes of competition and class struggle. While this logic provides a general explanation for uneven development, it is unable, on its own, to explain why growth favours some regions over others and why economic decline is concentrated in particular areas. In part this results from the limited nature of the thesis. The forms that the relations and forces of production may assume are influenced by social and political influences as well as economic ones. Although these forces were ignored in this work it is recognised that they play an important role in determining regional fortunes.

The analysis here also raises a number of further issues that must be addressed if we are to better understand the nature of economic growth and decline. Two areas of future research are particularly important. Firstly, while the Marxist model provides a viable explanation of economic crisis, it offers only a weak explanation of how the downturn in the rate of profit is halted. Clearly, the rate of profit cannot fall continuously. The analysis in Chapter 5 sheds some light on this issue, suggesting that capital-saving technical changes may increase the rate of profit. While Chapter 6 argues that capital-saving technical changes would be introduced to the economy when the price of capital increases relative to labour, it is unclear how relative factor prices would change in periods of recession. Secondly, the results in Chapter 7 demand further analysis of the processes of regional competition and in particular the determinants of the pace and direction of capital flows. The results in this chapter provide a strong argument for the importance of social policies to reduce problems of regional inequalities, yet they do not suggest what appropriate actions may be. Regional policies may temporarily ameliorate problems of regional disparities but they cannot prevent uneven development for it is an inevitable concomitant of growth in capitalist economies.

APPENDIX 1

A MODEL OF ECONOMIC GROWTH WITH NO TECHNICAL CHANGE

This appendix outlines the two department model of economic growth introduced in Chapter 4. The equations that define the model are presented and the existence of a solution to that set of equations is examined. The properties of the solution are then discussed.

The growth model is defined by the following equations which are explained in Chapter 4:

$$x_{1(t)} = a_{11}(1+g_{1(t)})x_{1(t)} + a_{12}(1+g_{2(t)})x_{2(t)} :$$

$$x_{2(t)} = D_{(t+1)}L_{(t+1)} + F_{(t)} :$$

$$L_{(t+1)} = l_1(1+g_{1(t)})x_{1(t)} + l_2(1+g_{2(t)})x_{2(t)} :$$

$$F_{(t)} = (1-b_{(t)})(1-\lambda_2 D_{(t)})L_{(t)} :$$

$$g_{(t)} = b_{(t)}\pi_{(t)} :$$

$$H_{(t)} = C_{(t)} + V_{(t)} :$$

where H represents the value of the capital stock :

$$I_{(t)} = b_{(t)}(1-\lambda_2 D_{(t)})L_{(t)} :$$

$\psi_{j(t)} = f(\pi_{1(t)}/\pi_{2(t)})$, where f( ) is a continuous and positive function of the departmental profit rates and $0 < \psi_j < 1$, for $j = 1,2$:

$$I_{j(t)} = \psi_{j(t)} b_{(t)} (1-\lambda_2 D_{(t)}) L_{(t)}, \quad \text{for } j = 1,2 :$$

$$H_{j(t)} = C_{j(t)} + V_{j(t)}, \quad \text{for } j = 1,2 :$$

$$g_{j(t)} = I_{j(t)}/H_{j(t)}, \quad \text{for } j = 1,2 :$$

$\Delta D/D_{(t)} = f[\Delta(L_{(t)}/N_{(t)})]$, where f( ) is a continuous and positive function of changes in the rate of employment.

It is assumed in the following analysis that a variable without a departmental subscript has the same value in both departments. In addition, it is assumed that:

$b_{(t)}$ is constant for all t:

$1 > \lambda_2 D_{(t)}$ for all t:

$\Delta N/N_{(t)} = g_{L(t)}$ is constant for all t.

After Webber (1987), the following propositions are used to determine whether or not this system of equations has a solution, and if it does, what properties the solution possesses.

Proposition 1: If $H(0) > 0$, then $f(H_{(t)}) > 0$ for all t.

Proof:

The value of the capital accumulated in period t+1 is

$$H_{j(t+1)} = H_{j(t)} + I_{j(t)}, \quad \text{for } j = 1,2.$$

$1 > \lambda_2 D_{(t)}$ for all t and thus

$$\pi_{j(t)} > 0, \quad \text{for } j = 1,2.$$

This in turn implies that

$$\psi_{j(t)} > 0, \quad \text{for } j = 1,2, \text{ and therefore}$$

$$I_{j(t)} = \psi_{j(t)} b_{(t)} (1-\lambda_2 D_{(t)}) L_{(t)} > 0.$$

Thus, $H_{j(t+1)} > H_{j(t)}$, if $H_{j(t)} > 0$, for j = 1,2.

Proposition 2: If H(0) > 0, f(H) is a continuous mapping from $R+^2$ to $R+^2$.

Proof:

$$H_{j(t+1)} = H_{j(t)} + I_{j(t)}, \quad \text{for } j = 1,2$$

$$= H_{j(t)} + \psi_{j(t)} b_{(t)} (1-\lambda_2 D_{(t)}) L_{(t)},$$

and ψ and D are both continuous functions of their respective arguments.

Proposition 3: f(H) is homogeneous of degree 1, so F(mH) = mf(H).

Proof:

Let $H^*_{j(t)} = mH_{j(t)}$, for j = 1,2.

Then, $H^*_{j(t+1)} = H^*_{j(t)} + I^*_{j(t)}$

$$= mH_{j(t)} + I^*_{j(t)}$$

$$= mH_{j(t)} + \psi^*_{j(t)} b^*_{(t)} (1-\lambda^*_2 D^*_{(t)}) L^*_{(t)}, \quad \text{for } j = 1,2.$$

$$\psi^*_{j(t)} = R \left[\frac{l^*_1(\lambda^*_1 a^*_{12} + \lambda^*_2 D^*_{(t)} l^*_2)}{l^*_2(\lambda^*_1 a^*_{11} + \lambda^*_2 D^*_{(t)} l^*_1)} \right] .$$

Techniques of production are unaffected by scale changes and so:

$$\lambda^*_1 = \lambda_1 \ , \ \lambda^*_2 = \lambda_2 \ :$$

$$a^*_{11} = a_{11} \ , \ a^*_{12} = a_{12} :$$

$$l^*_1 = l_1 \ , \ l^*_2 = l_2 \ :$$

In addition, $\Delta D/D_{(t)} = f[\Delta(L_{(t)}/N_{(t)})]$, and so the change in the scale of production will affect $D_{(t+1)}$ rather than $D_{(t)}$.

$b_{(t)}$ is assumed constant and is therefore unaffected by m.

$L^*_{(t)} = mL_{(t)}$, and therefore,

$$H^*_{j(t+1)} = mH_{j(t)} + \psi_{j(t)} b_{(t)} (1-\lambda_2 D_{(t)}) mL_{(t)}$$

$$= mH_{j(t)} + mI_{j(t)}, \quad \text{for } j = 1,2 .$$

Propositions 1-3 together imply that the function f(H) satisfies the conditions for the existence of a balanced growth path in the two department model. Thus, there exists a constant

$$g = g_{1(t)} = g_{2(t)} :$$

Subject to $H_{j(t+1)} = g\, H_{j(t)}$, for j = 1,2.

The stability and uniqueness of the growth path defined by g and H depend on the monotonicity of f(H). This characteristic of the growth path is examined next.

Proposition 4: Suppose that $H^*_{(t)} > H_{(t)}$ and that $H^*_{1(t)} = H_{1(t)}$ and $H^*_{2(t)} = mH_{2(t)}$, for $m \geqslant 1$. Then f(H) is monotonic if $H^*_{(t+1)} > H_{(t+1)}$.

Proof:

$$H^*_{1(t+1)} = H^*_{1(t)} + I^*_{1(t)}$$

$$= H_{1(t)} + I^*_{1(t)}$$

$$= H_{1(t)} + \psi_{1(t)} b_{(t)} (1-\lambda_2 D_{(t)}) L^*_{(t)} \quad \text{from Proposition 3.}$$

Therefore,

$$H^*_{1(t+1)} > H_{1(t+1)}, \text{ and}$$

$$H^*_{2(t+1)} > H_{2(t+1)}.$$

Thus, $H_{(t+1)}$ is a monotonic increasing function of $H_{(t)}$. The above propositions imply that g and H are positive and unique. Therefore the balanced growth path is stable.

APPENDIX 2

THE EFFECTS OF TECHNICAL CHANGES ON THE RATE OF PROFIT AND OTHER MEASURES OF ECONOMIC PERFORMANCE

The impact of technical change on the economy is identified using the techniques of comparative statics. These techniques are applied to the following system of equations that represent the two department economy. This model was introduced in Chapter 4. Here it is augmented by a number of related equations that define the rate of profit and its constituent variables. The model remains essentially the same as that of Chapter 4, though the real wage is specified slightly differenetly. The model is represented by the following 11 equations:

$$\pi = \frac{S}{C+V} : \qquad (A2.1)$$

$$S = (1-\lambda_2 D)L : \qquad (A2.2)$$

$$C = \lambda_1 K : \qquad (A2.3)$$

$$V = \lambda_2 DL : \qquad (A2.4)$$

$$K = a_{11}x_1 + a_{12}x_2 : \qquad (A2.5)$$

$$x_1 = (1+g)K : \qquad (A2.6)$$

$$x_2 = DL(1+g) : \qquad (A2.7)$$

$$L = l_1x_1 + l_2x_2 \ : \qquad (A2.8)$$

$$D = \frac{\gamma L}{N} \ : \qquad (A2.9)$$

$$\lambda_1 = \frac{l_1}{1-a_{11}} \ : \qquad (A2.10)$$

$$\lambda_2 = \frac{a_{12}l_1}{1-a_{11}} + l_2 \ . \qquad (A2.11)$$

The impact of technological innovation on this economy is evaluated by altering the values of the capital and labour input coefficients, tracing the effects of such change throughout the system and comparing the old and new equilibria. This is done in turn for each of the four input coefficients. The analysis has several steps. These are reviewed in the following example where the effect of changing the value of the capital input coefficient in department 1 is examined.

The first stage in the analysis is to find the total differentials of equations A2.1-A2.11. The variables in the system are the 11 terms on the left hand side of the equations and one of the input coefficients, in this case a_{11}, the capital input coefficient of department 1. The total differentials of equations A2.1 - A2.11 are respectively:

$$d\pi = \frac{1}{C+V}.dS - \frac{\pi}{C+V}.dC - \frac{\pi}{C+V}.dV \ : \qquad (A2.1a)$$

$$dS = (1-\lambda_2 D).dL - \lambda_2 L.dD - DL.d\lambda_2 \ : \qquad (A2.2a)$$

$$dC = \lambda_1.dK + K.d\lambda_1 \ : \qquad (A2.3a)$$

$$dV = \lambda_2 D.dL + \lambda_2 L.dD + DL.d\lambda_2 \ : \qquad (A2.4a)$$

$$dK = a_{11}.dx_1 + a_{12}.dx_2 + x_1.da_{11} \ : \qquad (A2.5a)$$

$$dx_1 = (1+g).dK \ : \qquad (A2.6a)$$

$$dx_2 = D(1+g).dL + L(1+g).dD \ : \qquad (A2.7a)$$

$$dL = l_1.dx_1 + l_2.dx_2 \ : \qquad (A2.8a)$$

$$dD = \frac{Y}{N}.dL \ : \qquad (A2.9a)$$

$$d\lambda_1 = \frac{l_1}{(1-a_{11})^2}.da_{11} \ : \qquad (A2.10a)$$

$$d\lambda_2 = \frac{a_{12}l_1}{(1-a_{11})^2}.da_{11} \ . \qquad (A2.11a)$$

The second stage of the analysis is to convert the differential equations into a matrix. In matrix form the above equations may be rewritten as

$$\mathbf{dU} = \mathbf{WdU} + \mathbf{w}da_{11} \ :$$

where $\mathbf{dU}$ is an 11x1 element column vector of the total differentials given above:

$\mathbf{W}$ is an 11x11 matrix of the partial derivatives of the above equations with respect to the eleven variables in the system:

w is an 11x1 element column vector comprising the partial derivatives of the 11 equations with respect to a_{11}.

Next, the matrix **W** is augmented by the vector **w** to yield an 11x12 matrix $\mathbf{W}^{+}$, which contains all the partial derivatives of equations A2.1a - A2.11a. The augmented matrix is then reduced to row echelon form solving for the total differentials. For a positive change in a_{11} the solutions of the system are:

$$d\pi = \frac{\{\pi^2\lambda_1 K\,[\,-L[1-a_{11}(1+g)] - l_2 x_2(1-a_{11})(1+g)] + [\pi^2 + \pi][-\lambda_1 DL^2 a_{12}[1-a_{11}(1+g)] + \lambda_2 l_1 x_1 x_2(1-a_{11})\}}{SL(1-a_{11})[1-a_{11}(1+g)]}.da_{11} \;:$$

$$dS = \frac{\{-\lambda_1 D^2 L^3 a_{12}[1-a_{11}(1+g)] - [S-V]l_1 x_1 x_2(1-a_{11})\}}{DL^2(1-a_{11})[1-a_{11}(1+g)]}.da_{11} \;:$$

$$dC = \frac{\{\lambda_1 KL[1-a_{11}(1+g)] + l_1 x_1[-l_1 x_1 + l_2 x_2]\}}{L(1-a_{11})[1-a_{11}(1+g)]}.da_{11} \;:$$

$$dV = \frac{\{\lambda_1 DL^2 a_{12}[1-a_{11}(1+g)] - 2\lambda_2 l_1 x_1 x_2(1-a_{11})\}}{L(1-a_{11})[1-a_{11}(1+g)]}.da_{11} \;:$$

$$dK = \frac{x_1[-l_1 x_1 + l_2 x_2]}{L[1-a_{11}(1+g)]}.da_{11} \;:$$

$$dx_1 = \frac{x_1(1+g)[-l_1x_1 + l_2x_2]}{L[1-a_{11}(1+g)]}.da_{11} :$$

$$dx_2 = \frac{-2l_1x_1x_2(1+g)}{L[1-a_{11}(1+g)]}.da_{11} :$$

$$dL = \frac{-l_1x_1x_2}{L^2[1-a_{11}(1+g)]}.da_{11} :$$

$$dD = \frac{-l_1x_1x_2}{DL[1-a_{11}(1+g)]}.da_{11} :$$

$$d\lambda_1 = \frac{l_1}{(1-a_{11})^2}.da_{11} :$$

$$d\lambda_2 = \frac{a_{12}l_1}{(1-a_{11})^2}.da_{11} .$$

For a change in a_{12}, the solutions of the system are:

$$d\pi = \frac{\pi\lambda_1 l_2 x_2^2 K\ [g-\pi]}{SL[1-a_{11}(1+g)]}.da_{12} :$$

$$dS = \frac{-\lambda_1 D^2L^3[1-a_{11}(1+g)] - [S-V]l_1x_2^2}{DL^2[1-a_{11}(1+g+]}.da_{12} :$$

$$dC = \frac{\lambda_1 x_2[-l_1 x_1 + l_2 x_2]}{L[1-a_{11}(1+g)]}.da_{12} :$$

$$dV = \frac{\lambda_1 DL^2[1-a_{11}(1+g)] - 2\lambda_2 l_1 x_2^2}{L[1-a_{11}(1+g)]}.da_{12} :$$

$$dK = \frac{x_2[-l_1 x_1 + l_2 x_2]}{L[1-a_{11}(1+g)]}.da_{12} :$$

$$dx_1 = \frac{x_2(1+g)[-l_1 x_1 + l_2 x_2]}{L[1-a_{11}(1+g)]}.da_{12} :$$

$$dx_2 = \frac{-2l_1 x_2^2(1+g)}{L[1-a_{11}(1+g)]}.da_{12} :$$

$$dL = \frac{-l_1 x_2^2}{L^2[1-a_{11}(1+g)]}.da_{12} :$$

$$dD = \frac{-l_1 x_2^2}{DL[1-a_{11}(1+g)]}.da_{12} :$$

$$d\lambda_1 = 0.da_{12} :$$

$$d\lambda_2 = \lambda_1.da_{12} .$$

For a change in l_1, the solutions of the system are:

$$d\pi = \frac{\pi l_2 x_2 K[g-\pi]}{SL[1-a_{11}(1+g)]}.dl_1 :$$

$$dS = \frac{D^2L^3a_{12}(1+g) - [S-V]x_1x_2(1-a_{11})}{DL^2(1-a_{11})(1+g)}.dl_1 :$$

$$dC = \frac{x_1[-l_1x_1 + l_2x_2]}{L(1+g)}.dl_1 :$$

$$dV = \frac{a_{12}x_2[-l_1x_1 + l_2x_2] - 2l_2x_2x_1(1-a_{11})}{L(1-a_{11})(1+g)}.dl_1 :$$

$$dK = \frac{-2x_1^2}{L(1+g)}.dl_1 :$$

$$dx_1 = \frac{-2x_1^2(1+g)}{L(1+g)}.dl_1 :$$

$$dx_2 = \frac{2x_1x_2(1+g)}{L(1+g)}.dl_1 :$$

$$dL = \frac{-x_1x_2}{L^2(1+g)}.dl_1 :$$

$$dD = \frac{-x_1x_2}{DL(1+g)}.dl_1 :$$

$$d\lambda_1 = \frac{1}{(1-a_{11})}.dl_1 :$$

$$d\lambda_2 = \frac{a_{12}}{(1-a_{11})}.dl_1 \ :$$

Finally, for a change in l_2, the solutions of the system are:

$$d\pi = \frac{\pi l_1 x_2 K[\pi-g]}{SL(1-a_{11})(1+g)}.dl_2 \ :$$

$$dS = \frac{-DL^2 - [S-V]x_2}{L}.dl_2 \ :$$

$$dC = -2D\lambda_1 x_1.dl_2 \ :$$

$$dV = -2\lambda_1 a_{12} x_1 + [l_1 x_1 - l_2 x_2].dl_2 \ :$$

$$dK = \frac{-2x_1 x_2}{L(1+g)}.dl_2 \ :$$

$$dx_1 = \frac{-2x_1 x_2 (1+g)}{L(1+g)}.dl_2 \ :$$

$$dx_2 = \frac{-2x_2^2 (1+g)}{L(1+g)}.dl_2 \ :$$

$$dL = \frac{-x_2^2}{L^2(1+g)}.dl_2 \ :$$

$$dD = \frac{-x_2^2}{DL(1+g)}.dl_2 \ :$$

$d\lambda_1 = 0.dl_2$:

$d\lambda_2 = 1.dl_2$:

APPENDIX 3

DATA SOURCES AND TECHNIQUES OF MEASUREMENT

The food and beverage industry is composed of 9 sub-sectors: meat and poultry products; fish products; fruit and vegetable processing; dairy products; flour and breakfast cereal products; feed products; bakery products; miscellaneous food products and beverage products. All data were measured on an annual basis and are published by Statistics Canada. The data used, their sources and the techniques of measurement are listed below. Unless specified otherwise, the data for both manufacturing as a whole and the food and beverage sector come from the same source. Techniques of measuring certain variables may differ between levels of spatial and sectoral aggregation. These differences are documented below.

1. **Output** This was measured as the value of shipments of goods of own manufacture. **Source:** General Review of the Manufacturing Industries of Canada (Catalogue 31-201).

2. **Wages** These data for manufacturing production workers only are provided directly. **Source:** General Review of the Manufacturing Industries of Canada (Catalogue 31-201).

3. **Energy Cost** This was measured as the cost of fuel and electricity used in production. These costs are provided directly. **Source:** General Review of the Manufacturing Industries of Canada (Catalogue 31-201).

4. **Material Cost** This is provided directly. **Source:** General Review of the Manufacturing Industries of Canada (Catalogue 31-201).

5. **Mid-Year Net Capital Stock** This variable for all components of production (plant and machinery) is provided directly. For all industries at the national level - **Source:** Fixed Capital Flows and Stocks (Catalogue 13-568). For all regional data - **Source:** Fixed Capital Flows and Stocks (Unpublished), available from Statistics Canada Construction Division.

6. **Depreciation** This variable is measured as capital consumption allowances for all components of production (plant and machinery) and is provided directly. For all industries at the national level - **Source:** Fixed Capital Flows and Stocks (Catalogue 13-568). For all regional data - **Source:** Fixed Capital Flows and Stocks (Unpublished), available from Statistics Canada Construction Division.

7. **Owned Inventory** These data are provided directly for individual industries for Canada as a whole. These data are collected monthly and annual averages were used here. **Source:** Inventories, Shipments and Orders in Manufacturing Industries (Catalogue 31-003). To obtain regional owned inventory data the national data for each industry was disaggregated by assuming that the proportion of owned inventory in each region was equal to the proportion of an industry's labour force found in that region. Regional data were obtained by summing the inventories for all industries in each region.

8. **Total Cost** This was measured as 2+3+4+6.

9. **Circulating Constant Capital Cost** This was measured as 3+4+6.

10. **Constant Capital Advanced** This is the sum of the mid-year net

capital stock and the constant capital proportion of the owned inventory. The constant capital proportion of the owned inventory was measured as (9/8)*7.

11. **Variable Capital Advanced** This is the variable capital proportion of the owned inventory. This was measured as (2/8)*7.

12. **Total Capital Advanced** This was measured as 10+11.

13. **Profit or Surplus** This is the difference between the value of output and the total costs of production. It was measured as 1-8.

14. **Price Rate of Profit** This is the ratio of the annual profit to the capital advanced. It was measured as 13/12.

15. **Manufacturing Selling Price Index** This variable for the manufacturing sector as a whole was estimated by dividing the current dollar value of the mid-year net capital stock (all components) for the manufacturing sector as a whole by the constant dollar value of the mid-year net capital stock. For the food and beverage sector this price index was obtained by the same procedure using the capital stock data for the food and beverage industry only. **Source:** Fixed Capital Flows and Stocks (Catalogue 13-568). Regional manufacturing selling price indexes were obtained by the same procedure using regional aggregates of capital stock data. **Source:** Fixed Capital Flows and Stocks (Unpublished), available from Statistics Canada Construction Division. The regional manufacturing selling price indexes for the food and beverage industry were all assumed to be equal to the national index for it was assumed that all food and beverage commodities traded in the same national market. Regional differences in the all industry aggregate selling price index were included to capture regional variatiomns in industry mix.

16. **Consumer Price Index** This is provided directly. **Source:** Consumer Price Index (Catalogue 62-001). This price index was not disaggregated by region or industry for in the absence of information on consumption patterns of workers by region and industry it was assumed that all workers purchase the same bundle of goods.

17. **Real Wage** This was measured as wages deflated by the consumer price index or 2/16.

18. **Hours Worked** This is provided directly for production workers and total employees. Hours worked for production workers only were used here. **Source:** General Review of the Manufacturing Industries of Canada (31-201).

19. **Hourly Real Wage** This was measured as real wages divided by hours worked or 17/18.

20. **Number of Turnovers** This was measured as the ratio of total costs of production to the owned inventory or 8/7.

21. **Rate of Exploitation**

a. For the Canadian manufacturing sector as a whole this was measured as the ratio of profits to wages or 13/2.

b. For the all industry aggregate at the regional level this was estimated using the following equation:

$$(1-\lambda_2 D)/\lambda_2 D \; : \qquad (A3.1)$$

where λ_2 represents the unit value of the aggregate consumer good see 23. This is assumed equal for all industries and all regions:

D is the average hourly real wage over all industries in the region.

c. For the food and beverage industry in all regions this was measured using equation A3.1 but where D represents the average hourly real wage in the Canadian food and beverage industry.

Note: It is assumed that a unit of labour-power in a given sector of production has the same value in all regions. For the manufacturing aggregate by region the rate of exploitation varies because of regional differences in the industrial composition.

22. **Value of Labour-Power**

a. For Canadian manufacturing as a whole this was measured by the following equation:

$$\lambda_L = 1/(e+1) :$$

where e denotes the rate of exploitation.

b. For the manufacturing sector by region this was measured as the product of the unit value of the aggregate consumer good (see 23) and the average manufacturing hourly real wage in the region.

c. For the food and beverage industry in all regions this was measured as the product of the unit value of the aggregate consumer good (see 23) and the average hourly real wage in the Canadian food and beverage industry.

23. **Unit Value of the Aggregate Consumer Good** This was obtained from the following equation:

$$\lambda_2 = \lambda_L/D .$$

Note: The Unit Value of the Consumer Good is assumed equal throughout the economy.

24. **Value Composition of Capital**

a. For the manufacturing sector as a whole across all regions this was measured as the ratio of the constant capital advanced to the variable capital advanced, or, 10/11.

b. For the Canadian food and beverage industry also this was measured as 10/11.

c. For the food and beverage industry at the regional level this was measured using the following equation:

$$VCC = \lambda_1 K/\lambda_L Lt' : \qquad (A3.2)$$

where all variables refer to the food and beverage industry:

λ_1 represents the unit value of the aggregate capital good see (26):

λ_L represents the value of labour power:

K/Lt' represents the technical composition of capital.

Note that this method of measuring the value composition of capital is consistent with the assumption that the aggregate capital good employed by firms in the food and beverage sector has the same unit value.

25. **Technical Composition of Capital** This was measured as the ratio of the deflated value of constant capital advanced to hours worked, adjusted for variations in turnover time, or, (10*15)*20/18.

26. **Unit Value of the Aggregate Capital Good** This was measured as the product of the value composition of capital and the unit value of labour power divided by the technical composition of capital, or, (24*22)/25. This is obtained by rearranging equation A3.2 and solving for λ_1.

27. **Value Rate of Profit** This was estimated from the following equation:

$$\pi_v = \frac{e}{(q+1)t'} :$$

where e is the value rate of exploitation:

q is the value composition of capital:

t′ is the inverse of the annual number of turnovers.

28. **Capacity Utilisation Rate** This was estimated by the same procedure employed by Statistics Canada. First, the mid-year net capital stock is divided by output, or 1/5. Second, the lowest capital/output ratio is found and this is assumed to represent full capacity output. Third, the capacity utilisation rate in other years is obtained by dividing the lowest capital/output ratio by the capital/output ratio of the respective year.

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