EMPIRICAL IDENTIFICATION OF THE RISK SHIFTING ASPECT OF LABOR MARKET IMPLICIT CONTRACTS

by

Edward Neil Gamber

Dissertation submitted to the Faculty of the

Virginia Polytechnic Institute and State University

in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

in

Economics

APPROVED:

Daniel Orr, Chairman

Richard Ashley

Richard Cothren

Sangmoon Hahm

Bruce Champ

May 1986

Blacksburg, Virginia

EMPIRICAL IDENTIFICATION OF THE RISK SHIFTING ASPECT OF LABOR MARKET IMPLICIT CONTRACTS

by

Edward Neil Gamber

Committee Chairman: Daniel Orr
Economics

(ABSTRACT)

Much of the recent work in the area of implicit contract theory hypothesizes that firms and workers differ in their attitudes towards risk. The optimal wage and employment contract calls for shifting some of the risk associated with a randomly fluctuating marginal product of labor from the more risk averse party to the less risk averse party. The purpose of this dissertation is to explore the empirical implications of this risk shifting hypothesis. In particular, the following question is addressed: "How can we empirically identify whether risk shifting is occurring in the labor market?"

Chapter 2 explores this question in the context of an implicit contract model with nominal variables and a randomly fluctuating price level. Under the usual assumption of risk neutral firms and risk averse workers the implications of the model are refuted by the industry level nominal wage stylized facts. Under the assumption that risk neutral workers insure risk averse firms the model is capable of explaining the stylized facts about the co-movements in nominal wages and employment.

Chapter 3 explores this question in the context of a long-term implicit contract model with bankruptcy constraints. It is shown that if risk neutral firms insure risk averse workers then the real wage will respond asymmetrically to permanent and temporary revenue function disturbances. In particular, the real wage will respond more to a given permanent shock than to a temporary shock of the same size.

Chapter 4 empirically tests this asymmetric wage response implication. A frequency domain technique is developed for decomposing a measure of revenue function disturbances into its permanent and temporary components and the real wage is regressed on each component. A sample of 12 4-digit SIC code industries are tested. The industry wage responses are estimated separately and as a system of seemingly unrelated regressions. Estimated separately, the results support the asymmetric response implication for 7 of the 12 industries at the .10 level of significance and 6 of the 12 industries at the .05 level. Estimated as a system the joint asymmetric response hypothesis is supported at the .01 level of significance for the 12 industries.

I dedicate this dissertation to

my parents.

ACKNOWLEDGMENTS

I especially wish to thank my dissertation chairman, Daniel Orr for helpful guidance and encouragement during the course of this project. I also wish to thank Richard Cothren for helping me develop many of the ideas which appear in this dissertation. Special thanks to Bruce Champ and Sangmoon Hahm for helpful comments and suggestions on all aspects of my work and thanks to Rick Ashley for help with the econometrics.

I thank Warren Weber, my original chairman, for being a patient and inspiring teacher throughout the course of my graduate studies. I thank Doug McManus for helpful discussions on both the technical and philisophical issues of writing a dissertation. I thank Jay Willard for typing this work. Finally, I thank the Earhart Foundation for financial support during my last two years of graduate studies.

TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF TABLES

LIFT OF FIGURES

FIGURE | Page

CHAPTER 1

INTRODUCTION AND LITERATURE REVIEW

1.1. Introduction

Much of the recent work in the area of implicit contract theory hypothesizes that firms and workers differ in their attitudes towards risk. The optimal wage and employment contract calls for shifting some of the risk associated with a randomly fluctuating marginal product of labor from the more risk averse party to the less risk averse party. The purpose of this dissertation is to explore the empirical implications of this risk shifting hypothesis. In particular, the following question is addressed: "How can we empirically identify whether risk shifting is occurring in the labor market?"

The key elements of implicit contract theory are that firms and workers find it mutually advantageous to be attached to one another for long periods of time and they differ in their preferences for risk. The outcome of an optimizing model with these elements is that the real wage is disassociated from the marginal product of labor. The stylized fact that the real wage is rigid is therefore explained by these models. But, a more important question is whether the real wage is playing a role in the optimal sharing of risk by the firm and worker.

The findings of this study are as follows. First, observing industry level stylized facts about co-movements in nominal wages and employment indicates that if risk shifting is occurring it is from risk averse firms to risk neutral workers. This result is demonstrated in Chapter 2. A very general implicit contract model which includes nominal variables and a randomly fluctuating price level is presented. Comparative statics results are worked out under two different assumptions about worker and firm risk preferences. Under the assumption that risk neutral firms insure risk averse workers, the wage and employment behavior described by the comparative statics results are inconsistent with the industry level stylized facts. Under the assumption that risk neutral workers insure risk averse firms the comparative statics results over some states of nature are consistent with the industry level stylized facts.

This is not to be taken to mean that risk neutral workers actually do insure risk averse firms, but, rather it should be an indication that co-movements in nominal wages and employment do not reveal much about the risk shifting aspect of implicit contracts. Even though the period-by-period movements in nominal wages and employment seem to indicate that risk neutral workers insure risk averse firms, the fact that the variance of the wage bill is smaller than the variance of profits for most industries indicates that firms are providing insurance to the workers. The conclusion is that we should look elsewhere for evidence of risk shifting in the labor market.

The second finding of this study is that risk shifting may be indentified by observing the response of the real wage to permanent and temporary disturbances to the firms' revenue function. This result is demonstrated in Chapter 3. A long term contracting model with bankruptcy constraints is presented, and in states of nature in which the bankruptcy constraints are binding, the wage becomes state dependent. The empirically testable implication of this is that if risk neutral firms insure risk averse workers then the real wage will respond asymmetrically to permanent and temporary shocks; i.e., the real wage will respond more to a permanent shock than to a temporary shock of the same size. More generally, if risk shifting is occurring then the longer the persistence of the shock the greater the contemporaneous real wage response.

The third finding of this study is that there is empirical evidence which is consistent with risk shifting in the labor makret. Chapter 4 presents empirical tests of the asymmetric wage response implication of the model presented in Chapter 3 using data from 12 4-digit SIC code industries. Industry output price is used as a proxy for revenue function disturbances. The output price data are decomposed by frequencies. The long frequencies are associated with the permanent movements in revenue and the short frequencies are associated with the temporary movements in revenue. The real wage is regressed on each component and the coefficient on the permanent component is tested to determine whether it is significantly larger than the coefficient on the temporary component. Eight out of the 12 industries sampled support the asymmetric response implication at the .10 level of significance. Six support the implication at the .05 level of significance, and the joint hypothesis that all 12 industries exhibit the asymmetric wage response, is supported at the .01 level of significance.

The remainder of this chapter presents a review of the literature on implicit contract theory. The dissertation then follows the outline described above. Chapter 5 contains a summary and conclusion.

1.2: Review of the Literature

The original intent of implicit contract theorizing was to provide a microeconomic explanation for the jointly observed phenomena of rigid wages and unemployment. Azariadis (1975), Baily (1974), and Gordon (1974) were the first contributions to this literature. Implicit contract theory departs from the Walrasian spot market model by recognizing that firms and workers place some value on maintaining long term relationships. The usual explanation for this is that the acquisition of firm specific human capital makes it costly for firms and workers to separate whenever the wage is different from the marginal product of labor. Firms in these models are therefore free to set employment and wages as long as their contract offers at least as much expected utility as other firms' contracts. In these early papers, risk averse workers and risk neutral firms choose a contract which specifies a state invariant or rigid wage and unemployment in bad states of nature.

The rigid wage result obtains because workers are willing to take a reduction in their average wage over all states of nature in exchange for a reduction in the variance of their wage. Firms can therefore attract the same size work force for a lower average wage by lowering the variance of the wage. It follows that the firm's profit maximizing strategy may be to fix the wage across all states of nature, providing complete wage insurance for workers. In good states of nature the wage is below the value of the marginal product of labor and the firm collects the insurance premium. In bad states of nature the wage is above the value of the marginal product of labor and the firm pays the worker the insurance benefit.

If a firm chooses a contract which specifies layoffs it must pay workers a risk premium. The higher the number of unemployed in any particular state of nature, the greater the risk premium must be. For some state of nature, if the reduction in the firm's wage bill resulting from laying off a worker is greater than the increase in the premium, the firm will choose to lay off an additional worker in that state of nature. A firm will continue to lay off workers in a particular state of nature until the marginal increase in the unemployment premium just equals the amount that the firm saves by reducing its work force in that state.

Although these early works seem to establish an explanation for the rigid wage-unemployment phenomena, several problems with the analysis remain unsolved. Three main problems will be discussed here: the enforcement problem, the inefficient employment problem and the macroeconomic-nominal wage problem. The purpose of this review is to highlight the major developments in implicit contract theory and show that the question of whether we can empirically identify the risk shifting aspect of these contracts has been largely ignored.

The enforcement problem arises because of the implicit nature of these contracts. If we are assuming that firms and workers act as if contracts exist then we must also examine the conditions under which the contracts are binding. If a spot market exists for labor, and firms and workers can enter and exit the spot market costlessly, then either the firm or the worker will always have incentive to break the implicit agreement. In states where the firm pays the worker a wage below the value of his marginal product, the worker has incentive to quit and seek employment on the spot market. In states where the firm pays the worker a wage above the value of his marginal product, the firm has incentive to fire its work force and hire labor on the spot market.

The early works by Azariadis, Baily and Gordon relied on mobility costs to enforce the contracts on the labor side but left open the problem of firms breaking the contracts. Grossman (1977) and others suggest that reputation may enforce the contracts on both sides. Firms and workers may wish to avoid earning reputations as contract breakers since it could possibly make contracting in the future either costly or impossible.

Recent work by Holmstrom (1981, 1983), involves a bonding scheme to enforce the contracts. Workers and firms in his model agree on two period contracts. In the first period, workers are paid a wage below the value of their marginal product. In the second period, workers are paid a wage above the value of their marginal product. Workers are essentially posting a bond in the first period which they receive back in the second. If they quit before the second period, they forego the bond. Although this scheme enforces contracts on workers it leaves firms free to fire workers in the second period of the contract. A similar bonding scheme can act as an enforcement mechanism for firms but both firms and workers cannot bond at the same time, leaving open the possibility that one party will renege on the contract.

Bull (1983) considers the enforcement problem in a model without mobility costs, risk sharing or reputation. Firms and workers are both risk averse and, in addition to the contract market, there is a spot market for labor which both firms and workers can participate in costlessly. Under the assumption that the labor contract specifies a wage in exchange for labor time, Bull demonstrates that contracts will always be broken in the ex post period by either firms or workers. He then contrasts this with the case where the wage is a payment for both work time and level of effort. The realized spot market wage will differ from the contracted wage in the ex post period with probability 1, but, in contrast to the labor time only case, the spot market level of effort may be such that both parties would be worse off if the contract were broken. Bull generalizes this idea by showing that the existence of an enforceable contract requires only that firms and workers trade some good for which there is no outside market.

The second main problem with the early implicit contract literature involves the inefficient employment issue. Is the level of employment generated in the early implicit contract models inefficient in the sense that there is some Pareto improving movement in wages and employment that would make both firms and workers better off? The answer is yes but the inefficiency is in the direction of overemployment. In the symmetric information models exemplified by Azariadis, Baily and Gordon, the marginal rate of substitution between leisure and consumption is greater than the marginal product of labor in the lay off states of nature. As pointed out by Akerlof and Miyazaki (1980), if the firm is allowed to provide unemployment insurance as well as wage insurance then the overemployment is also eliminated. These findings shifted the emphasis of implicit contract research towards exploring conditions under which equilibrium in the labor market is characterized by inefficient levels of employment. It was found that by assuming that firms and workers possess asymmetric information concerning the true state of nature the optimal contract may call for inefficient levels of employment in certain states of nature. (See the Quarterly Journal of Economics, 1983 Supplement for a collection of asymmetric information implicit contract models.)

In an asymmetric information model the firm is usually assumed to have superior knowledge about the true state of the world. For example, the firm may directly observe the shock to the production function. The form of analysis applied in these models is much like the analysis of insurance markets in Rothschild and Stiglitz (1976). Truth telling constraints are added to the model and the outcome, in general, departs from the full information spot market outcome. The reason for this is that truth telling constrains the firm to employ an inefficient number of workers in states where the firm would normally lie. In other words, to prevent the firm from lying in certain states, the contract must specify a wage and level of employment which leaves the firm indifferent between lying and revealing the true state of nature. Chari (1983) and Green and Kahn (1983) find overemployment in good states of nature when firms are risk neutral and workers are risk averse.

Azariadis (1983) finds that underemployment occurs in bad states of nature when firms are, at the margin, more risk averse than workers.

The most appealing assumption about risk preferences is that firms are risk neutral and workers are risk averse, or, more generally, firms are less risk averse than workers. As mentioned above, models with this assumption about risk preferences produce overemployment in certain states of nature. Recent works by Kahn and Scheinkman (1985) and also Farmer (1985) have shown that if firms face a binding bankruptcy constraint in certain states of nature, the models are capable of producing underemployment. The effect of a bankruptcy constraint is to make the firm appear to be risk averse in states in which the constraint is binding.

The third main problem with implicit contract research is the macroeconomic-nominal wage problem. The original intent of implicit contract theory was to explain the jointly observed phenomena of rigid wages and unemployment. The models discussed here fall short of explaining macroeconomic behavior. First, the wage rigidity or stickiness that emerges from these models is in terms of the real wage, not the nominal. Second, most of the implicit contract modelling has been partial equilibrium (an exception is Farmer (1984)), and hence they are not appropriate for explaining economy-wide cyclic unemployemnt.

The inability of the implicit contract model to explain aggregate nominal wage stickiness was first pointed out by Barro (1977). Barro's criticism was aimed at works by Gray (1976,1978) and Fischer (1977a, 1977b), which made reference to the implicit contract literature to justify their fixed nominal wage contracts. A crucial assumption in the

Gray-Fischer type of model is that firms and workers fix the nominal wage ex ante allowing the real wage and level of employment to be determined by the labor demand curve ex post. This implies that unanticipated nominal shocks lead to dead weight losses. Barro simply asks why firms and workers would agree to a contract which imposes ex post dead weight losses. He asserts that the optimal contract is the contract that maximizes the total pie possessed by the firm and the worker. In the presence of nominal disturbances, Barro claims that the optimal contract may call for fixing the level of employment and allowing the real wage to fluctuate.

Waldo (1981) analyzes the nominal wage implications of the implicit contract theory in an effort to formalize Barro's criticism of the Gray-Fischer contracting scheme. In a single good economy he considers the response of the nominal wage and employment to changes in the price level when complete indexation is possible. The result, as expected, is that the nominal wage changes to maintain a constant real wage and employment remains unchanged. He then considers what happens when the nominal wage is fixed ex ante and cannot be changed once the state of nature is revealed. Under this assumption the sign on the relationship between employment and the real wage is ambiguous. In short, implicit contracts cannot explain the type of nominal wage stickiness which contracting models, such as those in Gray and Fischer, rely upon for their results.[1]

In his 1984 American Economic Association presidential address, Charles Schultze explores extensions of the implicit contract model in an effort to explain macroeconomic nominal wage stickiness. He begins by pointing out that implicit contract models in the current literature assume that there exists a fixed distribution which attaches probabilities to all possible states of nature, that is, they assume the existence of risk but not uncertainty.

> "Most of the mathematical modeling of implicit contracts has assumed that workers and firms base their agreements on a known probability distribution (presumably commonly held) of the relevant variables, most importantly the marginal revenue product of labor or some related variable." (Schultze (1985), p. 4)

Schultze claims that if we extend the implicit contract model to include uncertainty as well as risk then nominal wage stickiness follows directly from the real wage stickiness implied by the standard implicit contract model. On an intuitive level Schultze's argument is convincing. Incorporating uncertainty into an explicit model, however, is difficult since it would involve specifying rules for recontracting in the event that something occurs that is totally outside of our present realm of possibilities.

The review of the literature here has been necessarily selective since the amount that has been written on the subject of implicit contracts is vast. Three points should be evident from this review, however. First, current work has moved away from explaining the joint phenomena of wage stickiness and unemployment and is now concerned with generating conditions under which employment deviates from Walrasian spot market levels. Reviews of this current work can be found in Azariadis and Stiglitz (1983) and Rosen (1985). Second, one particular nominal wage implication has been ruled out. As pointed out by Barro and formalized by Waldo, implicit contracts cannot explain the type of nominal wage stickiness associated with the Gray-Fischer contracting models. Although Schultze has suggested a way to salvage nominal wage stickiness from implicit contracts, incorporating uncertainty into the model calls for a major restructuring of the problem. Third, very little work has been done on explicitly testing the implications of the model. (Raisian (1983), is an exception.) Most importantly, the empirical implications of the risk shifting aspect of these contracts has not been properly addressed. In view of the fact that risk shifting is an integral part of the implicit contract theory it is important to determine ways in which it is revealed in the data. This dissertation addresses the question of whether we can empirically identify risk shifting by observing co-movements in the industry level nominal wage and level of employment and the real wage response to permanent and temporary shocks. It is found that the later does reveal evidence about risk shifting which is supported by industry level data.

FOOTNOTES

[1]Other authors have also demonstrated this result; see Grossman and Hart (1980).

CHAPTER 2

EVIDENCE OF RISK SHIFTING IN INDUSTRY LEVEL NOMINAL WAGE AND EMPLOYMENT BEHAVIOR

2.1 Introduction

The purpose of this chapter is to investigate whether we can identify risk shifting by observing the following stylized facts about industry level nominal wage and employment behavior:

1. The nominal wage tends to move very little in response to changes in industry output prices.

2. When the nominal wage does respond it is usually positively related to industry output prices.

3. Employment is consistently positively related to industry output prices.

The main finding of this chapter is that these patterns will not occur if risk neutral firms insure risk averse workers against real income fluctuations. A model in which risk neutral workers insure risk averse firms, on the other hand, can be reconciled with these observations.

The intuition behind this result can be seen in the following simple example. If the general price level rises by more than the firm's output price then the firm suffers a decline in its relative output price. Regardless of what is assumed about risk aversion, the firm will always reduce employment when such a state occurs. Under the assumption that the firm insures the worker, the firm attempts to stabilize the worker's marginal utility of consumption. In the situation described above, the firm would be required to increase the nominal wage in order to stabilize the worker's marginal utility of consumption in the face of a declining demand for the workers labor services. What we tend to observe is that when a firm's output price rises by less than the price level, the nominal wage tends to remain constant or decline. It appears as if the worker is insuring the firm against declines in its output price relative to the price level.

Two features of this analysis distinguish it from earlier work. First, this study considers an implicit contract model with nominal variables and a randomly fluctuating price level. The firm chooses a nominal wage instead of a real wage. Second, this analysis is concerned with the more general implications of the implicit contract model in relation to the observed wage and employment patterns, whereas earlier studies and other recent papers on implicit contract theory have been concerned with finding conditions under which equilibria are characterized by inefficient levels of employment. Examples are found in the asymmetric information models of Azariadis (1983), Chari (1983), and Green and Kahn (1983) and also the recent work which has incorporated bankruptcy constraints to generate inefficient levels of employment as in Farmer (1985) and Kahn and Shienkman (1985).

2.2: An Implicit Contract Model with Nominal Variables

This section analyzes the nominal wage and employment implications of an implicit contract model in an economy where the firm's output price and the price level are jointly distributed stationary processes. The main difference between the model presented here and previous implicit contract models is that the price level is not fixed. The model starts with the empirically reasonable assumption that when the price level rises (or falls) the output prices in some industries are rising (or falling) more than the average and some industry's output prices are rising (or falling) less than the average. Over all states of nature, the expected value of a particular industry output price relative to the price level will remain constant (this follows from the stationarity assumption), but across states of nature the industry will experience changes in its output price relative to the price level.

The model yields the following results. First, under the assumption that firms are risk neutral and workers are risk averse it is not possible to reconcile the model's implications for the nominal wage with the stylized facts. Second, under the assumption of risk neutral workers and risk averse firms the model may explain observed nominal wage behavior. The model's implications about employment are consistent with the observed behavior regardless of the assumption about risk preferences.

The Model

Prices. To begin we assume that the economy consists of M industries, each producing a different consumption good. Each industry contains a large number of competitive firms. The equilibrium nominal price of output in industry i is denoted by P_i for $i = 1,\ldots M$. The equilibrium real quantity of output in industry i is denoted by q_i for $i = 1,\ldots,M$. The M nominal prices are jointly distributed stationary random variables with a joint probability density function $h(P_1,\ldots,P_M)$. The q_i's are random variables also. Each q_i is a function of all M nominal prices so we may therefore fully characterize a state of nature by the realization of the M nominal output prices.

The price level is defined as a weighted average of the M output prices:

$$\overline{P} = \sum_{j=1}^{M} \alpha_j P_j \quad \text{where } \alpha_j = \frac{q_j}{\sum_{i=1}^{M} q_i}, \quad j=1,\ldots,M.$$

We will be considering a representative firm and a representative worker in industry 1. It follows from a simple transformation of variables that the definition of $\overline{P}$ and the joint probability density function over the random variables P_1, P_2, ... P_M imply a joint probability density function over P_1 and $\overline{P}$ which we denote by $g(P_1,\overline{P})$. (See Appendix 1 for the construction of $g(P_1,\overline{P})$).

<u>The Representative Firm</u>. We consider a representative firm in industry 1. The firm maximizes the expected utility of profits over a single time period by choosing a state contingent nominal wage denoted by the function $W(P_1,\overline{P})$ and a state contingent level of employment denoted by the function $L(P_1,\overline{P})$. The firm's expected utility of profits is written as follows:[1]

$$V^e = \int_{P_1}\int_{\overline{P}} V\left(\frac{P_1}{\overline{P}} f(L) - \frac{W}{\overline{P}} L\right) g(P_1,\overline{P})\, d\overline{P}\, dP_1 \qquad (2.1)$$

The firm's production function is assumed to be strictly concave, that is, $f' > 0$, $f'' < 0$. The firm's utility of profits function is assumed to be concave, that is, $V' > 0$, $V'' < 0$. The effects of altering this assumption are examined later.

The Representative Worker. We consider a representative worker in industry 1. The worker's objective is to maximize expected utility by choosing a state contingent consumption bundle denoted by $C(P_1,\overline{P})$ and state contingent leisure denoted by $T(P_1,\overline{P})$. The worker's expected utility is written as follows:

$$U^e = \int_{P_1} \int_{\overline{P}} U(C,T) g(P_1,\overline{P}) d\overline{P} dP_1, \tag{2.2}$$

where maximization takes place subject to the following constraints:

$\overline{P}C \leq WL$	for all $P_1,\overline{P}$	(2.3a)
$C \geq 0$	for all $P_1,\overline{P}$	(2.3b)
$\tau - T = L$	for all $P_1,\overline{P}$	(2.3c)
$L \geq 0$	for all $P_1,\overline{P}$	(2.3d)

τ is the total time available. It is assumed that the consumption bundle C is nonstorable and that the worker has no other forms of wealth other than current period income.

The utility function is concave, that is, $U_1,U_2 > 0$ and $U_{11},U_{22} \leq 0$. Further, we assume that the following conditions hold for all states of nature:

$$U_{11}\frac{W}{\overline{P}} - U_{12} < 0 \text{ and } U_{22} - \frac{W}{\overline{P}}U_{12} < 0, \tag{2.4}$$

which are sufficient to guarantee that consumption and leisure are normal goods.

Given these restrictions on utility and the nonstorability of the consumption good we can rewrite expected utility as follows:

$$U^e = \int_{P_1} \int_{\overline{P}} U(\frac{W}{\overline{P}} L, \tau - L) g(P_1, \overline{P}) d\overline{P} dP_1. \qquad (2.5)$$

<u>The Optimal Contract</u>. Before deriving the optimal contract a discussion of the underlying assumptions is in order. First, the maximization in an implicit contract model is carried out by the firm. The firm chooses both the wage and the quantity of labor. The assumption underlying this monopsony power is that workers are somehow attached to the firm in the short run. The explanation for this attachment may be that workers have some firm specific human capital which would be lost if they switched to another firm. More simply, they may face some fixed cost of moving to another job. Or, as pointed out by Bull (1983), there may be a good for which there is no market which firms and workers wish to trade. In the model presented here that good is income insurance.

The assumption of worker attachment "allows" the firm to pay the worker a real wage which differs from the value of his marginal product. If we assume that there is a spot market for labor in addition to the contract market then in the absence of worker attachment, the firm would be forced to pay the worker the value of his marginal product in each state of nature.

To capture this worker attachment assumption, the firm is assumed to maximize expected utility of profits subject to the constraint that its contract offers workers a level of expected utility that is at least as great as that offered by other firms in the economy.

Alternative wage and employment opportunities are given by the set of contracts $\{W_i, L_i\}_{i=1}^{N}$, where N is the number of firms offering contracts in the economy. The firm's maximization problem is written as follows:

$$\max_{\{W,L\}} \pi^e = \int_{P_1} \int_{\overline{P}} V\{\frac{P_1}{\overline{P}} f(L) - \frac{W}{\overline{P}} L\} g(P_1, \overline{P}) d\overline{P} dP_1 \qquad (2.6)$$

subject to:

$$\int_{P_1} \int_{\overline{P}} U(\frac{W}{\overline{P}} L, \tau - L) g(P_1, \overline{P}) d\overline{P} dP_1 \quad > \quad \overline{U}_i \qquad (2.7)$$

where:

$$\overline{U}_i = \int_{P_i} \int_{\overline{P}} U(\frac{W(P_i, \overline{P})}{\overline{P}} L(P_i, \overline{P}), \ \tau - L(P_i, \overline{P})) g_i(P_i, \overline{P}) d\overline{P} dP_i$$

In equilibrium we will assume that each firm offers a contract which provides for an expected utility equal to $\overline{U}$, i.e., $\overline{U}_i = \overline{U}$ for all i. This is simply a no arbitrage condition in the expected utility of the offered contracts.

Constructing the Lagrangian function $J(W(P_1,\overline{P}), L(P_1,\overline{P}),\lambda)$ and assuming that an interior solution exists we have the following first order conditions for profit maximization.[2]

$$\frac{\partial J}{\partial L} = V'\left(\frac{P_1}{\overline{P}}f' - \frac{W}{\overline{P}}\right) + \lambda\left(U_1 \frac{W}{\overline{P}} - U_2\right) = 0 \qquad (2.8)$$

for all P_1 and $\overline{P}$.

$$\frac{\partial J}{\partial W} = -V' + \lambda U_1 = 0 \qquad \text{for all } P_1 \text{ and } \overline{P}. \qquad (2.9)$$

$$\frac{\partial J}{\partial \lambda} = \int_{P_1}\int_{\overline{P}} U\left(\frac{W}{\overline{P}} L, \tau - L\right) g(P_1,\overline{P})\,d\overline{P}\,dP_1 - \overline{U} = 0 \qquad (2.10)$$

First order condition (2.9) is the usual optimal risk sharing condition. Combining (2.8) and (2.9) we get the usual efficiency condition:

$$\frac{P_1}{\overline{P}}f' = \frac{U_2}{U_1}.$$

As shown in Appendix 3, condition (2.9) implies a rigid real wage if the following assumptions are met.

(i) Firms are risk neutral and workers are risk averse.

(ii) Utility is separable in consumption and leisure.

(iii) The employment variable is discrete, i.e., the firm adjusts employment through layoffs and recalls rather than adjusting hours.

The model presented here assumes that L is a continuous variable. This is assumed so as not to restrict the firm to an employment rule involving full employment vs. layoffs. Here L is interpreted as the number of labor hours demanded of the representative worker. Since all workers are identical, changes in L are the same for all the firm's workers.

Alternatively, the problem could be set up where L represents the total number of labor hours demanded by the firm and the utility function given by (2.5) is then interpreted as the utility of the labor force attached to the firm. The firm is free to choose some combination of layoffs and work reduction to achieve some total L as long as, over all states of nature, the expected utility of its work force is equal to $\overline{U}$.

Interpretation of the first order conditions (2.8), (2.9) and (2.10) under this more general assumption about the labor choice variable implies nothing about the behavior of the real wage across states of nature. In order to derive some implications from this model we must totally differentiate the first order conditions and examine what happens to W and L as we move across states of nature. A technique for doing this which can be found in Rosen (1985) and Browning et al. (1985) is to consider λ to be a nusance parameter and totally differentiate (2.8) and (2.9).[3]

This technique is employed to derive expressions for $\frac{dW}{W}$ and $\frac{dL}{L}$ under two different assumptions about worker and firm preferences. The details of the comparative statics are relegated to Appendix 2.

<u>Assumption 1</u>. Workers are risk averse and firms are risk neutral. This assumption implies that V' is equal to a constant, V'' = 0 and

U_{11}, U_{22} are strictly less than zero. The resulting expressions for the nominal wage and employment are as follows:

$$\frac{dW}{W} = \frac{d\overline{P}}{\overline{P}} - \gamma_1\left(\frac{dP_1}{P_1} - \frac{d\overline{P}}{\overline{P}}\right) \tag{2.11}$$

$$\frac{dL}{L} = \gamma_2\left(\frac{dP_1}{P_1} - \frac{d\overline{P}}{\overline{P}}\right). \tag{2.12}$$

Using the concavity and normality assumptions, γ_1 and γ_2 are positive. (See Appendix 2 for explicit forms of γ_1 and γ_2.)

The interpretation of these results is straightforward if we think of the real variables involved. If firms are risk neutral and workers are risk averse the optimal contract calls for the firm to insure the worker against fluctuations in the marginal utility of consumption. When the firm's output price rises relative to the price level the firm is experiencing a good state of nature. Profit maximization calls for increasing employment, but, in order to maintain the worker's constant marginal utility of consumption the firm must decrease the real wage.

If the good state of nature occurs during a rise in the price level, the firm will simply increase the nominal wage by less than the price level to achieve a reduction in the real wage. If the good state of nature occurs during a decrease in the price level the firm will decrease the nominal wage by more than the reduction in the price level to achieve a reduction in the real wage. If a bad state of nature occurs during a rise in the price level, the firm will increase the nominal wage by more than the increase in the price level in order to achieve an increase in the real wage. If a bad state of nature occurs during a decrease in the price level the firm will decrease the nominal wage by less than the decrease in the price level in order to achieve an increase in the real wage.

The conclusion to draw is that the predictions of the model for the nominal wage under this assumption are not consistent with the observed behavior of wages. The predictions for employment are consistent with the observations, i.e., employment rises in good states of nature and falls in bad.

Assumption (2). Firms are risk averse and workers are risk neutral. Under this assumption $V'' < 0$ and we rewrite the utility function (5) as follows:

$$U = \frac{WL}{\overline{P}} + \tau - L$$

Carrying out the comparative statics problem we get the following expressions for the nominal wage and employment:

$$\frac{dW}{W} = \frac{d\overline{P}}{\overline{P}} + \gamma_3\left(\frac{dP_1}{P_1} - \frac{d\overline{P}}{\overline{P}}\right), \tag{2.13}$$

$$\frac{dL}{L} = \gamma_4\left(\frac{dP_1}{P_1} - \frac{d\overline{P}}{\overline{P}}\right), \tag{2.14}$$

(See Appendix 2 for explicit forms of γ_3 and γ_4).

Using the concavity assumption on the production function γ_4 is positive. If the marginal product of labor is less than the real wage then the sign of γ_3 is ambiguous. If, however, the marginal product of labor is greater than the real wage then γ_3 is unambiguously positive. The intuition behind this wage result can be clearly seen by examining first order condition (2.9), which, under the assumption that firms are risk averse and workers are risk neutral, becomes the following:

$$V' = \lambda,$$

which implies that the optimal contract calls for constant profits across states of nature. Consider the case where the firm is paying the worker a real wage below the value of the marginal product of labor. If a good state of nature occurs the firm increases employment and the real wage in order to stabilize profits. Similarly, if the firm experiences a bad state of nature it decreases employment and the real wage. The implication for the nominal wage is that if the firm experiences a relative price decline in the face of a rising price level then a fixed or declining nominal wage is called for by the optimal contract. Symmetrically, if the firm experiences a relative price increase in the face of a declining price level then the optimal contract again calls for a fixed or increasing nominal wage.

Consider the case where the firm is paying the worker a real wage above the marginal product of labor. In this case the sign on the wage is ambiguous. An increase in the firm's relative output price implies an increase in employment, the firm's profits may increase, decrease, or remain the same without altering the real wage.

2.3. Summary and Conclusions

The point of the preceeding section was not to suggest that workers actually insure firms but rather, to show that under the usual assumption that firms are risk neutral and workers are risk averse, the model's predictions are inconsistent with the observed behavior of nominal wages.

The results presented here depend upon two features of the implicit contract model which should be reexamined if observed wages and employment are to be explained as the result of risk sharing in the labor market. First, the model presented here is essentially a comparative statics problem. A more general concept of firms insuring workers would be reflected in the simple prediction that profits fluctuate more than wage income. If firms are risk neutral and workers are risk averse, with utility functions separable in consumption and leisure, then the implicit contract model predicts a lower variance for wage income than for profits. The optimal contract calls for fixing wage income across states of nature. If firms are risk averse and workers are risk neutral then the optimal contract calls for fixing profits across states of nature. The variance of profits is less than the variance of wage income. The fact that profits vary more than wage income is therefore consistent with firms insuring workers, but the observed response of wages to actual changes in states of nature is inconsistent with such a model. This contradictory evidence suggests that observing the stylized facts about co-movements in nominal wages and employment will not provide us with information about risk shifting in the labor market. Richard Cantor (1984) has constructed an implicit contract model in which explicit variances are obtained and, under the assumption that workers are restricted from borrowing against their human capital, he demonstrates that the optimal contract generates a higher variance for profits than for wages.

The second feature of this model which should be considered in future research is that it does not take into account permanent changes in states of nature. The fluctuations in relative prices in this model are purely transitory.

Intuition suggests that a risk neutral firm would be willing to insure a risk averse worker against temporary fluctuations in his marginal product of labor. If, however, the firm experiences a permanent decrease in the relative price of its output, income insurance may no longer be feasible since it may lead to bankruptcy. If the firm experiences a permanent increase in its relative price of output it may wish to permanently increase the real wage in order to attract a larger pool of workers. A simplified version of this problem is worked out in the following chapter and it is shown that risk shifting may be identified by observing the response of the real wage to permanent and temporary shocks to the firms' revenue function.

FOOTNOTES

[1]For notational ease the functional notation has been dropped. The variables L, W, C, and T are implicitly functions of P_1 and $\bar{P}$.

[2]This is an isoparametric problem in the calculus of variations. The full Lagrangian function is written out in Appendix 2.

[3]Browning et al. (1985) shows that additive separability of preferences are necessary to use this technique. Preferences are additively separable across states of nature in this model.

CHAPTER 3

EVIDENCE OF RISK SHIFTING IN THE REAL WAGE RESPONSE TO PERMANENT AND TEMPORARY SHOCKS

3.1 Introduction

The purpose of this chapter is to investigate whether risk shifting can be identified by observing the real wage response to permanent and temporary disturbances to the firms' revenue function. This question is investigated in the context of a long term contracting model with bankruptcy constraints. Firms and workers decide upon a two period wage contract in the face of both permanent and temporary shocks to the firm's revenue function. For states in which the bankruptcy constraints are binding the wage is state dependent. The empirically interesting implication of the model is that it predicts an asymmetric response of the real wage to permanent and temporary shocks. In particular, the real wage responds more to a given permanent shock than to a temporary shock of the same size. The intuition behind this result can be seen by considering the case where the firm experiences a positive temporary shock. Since the optimal contract calls for smoothing the workers' income, the firm will save part of the increase in output to augment the second period wage. If the firm experiences a permanent shock of the same size no saving is required since a shock of the same size will occur in period 2. In contrast, if the firm is not insuring the worker then the response of the real wage to permanent and temporary shocks will be the same.

Two features of this model distinguish it from earlier work on implicit contract theory. First, the model considers the behavior of firms and workers over a two period time horizon. There have been other two period models in the literature (see Holmstrom (1983), for example) but these have dealt with the enforcement issue, not the empirical identification of risk shifting. The importance of considering a two period time horizon is that it allows us to examine the effects of nonstationary disturbances to the firm's revenue function. The second feature of this model which distinguishes it from earlier work is that it makes a distinction between permanent and temporary disturbances to the firm's revenue function.

The following section presents the model and its implications for the behavior of the real wage. Section 3.3 discusses empirical considerations of the model. This chapter concludes with a summary and a discussion of extensions of the model.

3.2 A Two Period Implicit Contract Model with Permanent and Temporary Shocks

The model presented here considers the choice problem faced by a representative risk neutral firm in a single good economy. The firm's objective is to maximize expected profits over a two period horizon by choosing a contract which specifies a state contingent wage payment for each period. Employment is fixed at one[1] and the state of nature each period is given by the realization of the firm's random output.

The firm's output in period 1 is equal to the sum of two random variables:

$$Y_{ij} = \nu_i + \varepsilon_j,$$

where ν_i, $i = 1,\ldots,M$ is the permanent shock to output and ε_j, $j = 1,\ldots,N$ is the temporary shock. The firm's output in period 2 is equal to the sum of two random variables:

$$\hat{Y}_{ik} = \nu_i + \hat{\varepsilon}_k$$

where ν_i is the period 1 permanent shock and $\hat{\varepsilon}_k$, $k = 1,\ldots,N$ is the period 2 temporary shock. The vectors ν, ε, and $\hat{\varepsilon}$ are elements of R^M_+, R^N_+ and R^N_+ respectively.

The distributions of these random variables are known by the firm and the worker. We specify that the probability of ν_i is ρ_i, the probability of ε_j is q_j and the probability of $\hat{\varepsilon}_k = q_k$. The usual properties apply to these distributions, that is:

$$0 < \rho_i < 1, \quad i = 1,\ldots,M, \quad \sum_i \rho_i = 1$$

$$0 < q_j < 1, \quad j = 1,\ldots,N, \quad \sum_j q_j = 1$$

$$0 < q_k < 1, \quad k = 1,\ldots,N, \quad \sum_k q_k = 1.$$

For simplicity, we assume that ν, ε and $\hat{\varepsilon}$ are independently distributed so that the probability of a particular ν_i, ε_j, $\hat{\varepsilon}_k$ occurring is equal to $\rho_i q_j q_k$.

We denote the state contingent wage in period 1 by W_{ij} and the state contingent wage in period 2 by $\hat{W}_{ijk}$. Each wage is contingent on all current and past information. The firm's expected profits can be written as follows:

$$\pi^e = \sum_i \sum_j \rho_i q_j (Y_{ij} - W_{ij}) + \beta \sum_i \sum_j \sum_k \rho_i q_j q_k (\hat{Y}_{ik} - \hat{W}_{ijk}), \quad (3.1)$$

where $\beta = 1/1+r$ is the nonstochastic discount rate and r is the real interest rate.

The Worker

Although employment is fixed at 1, the firm faces the constraint that it must offer a level of expected utility at least as great as that offered by other firms, in order to retain the worker. We denote the equilibrium level of expected utility by $\bar{U}$.

The worker's utility is a function of the consumption good. We assume that the utility function is concave and separable over the two time periods. The consumption good is nonstorable and the worker has no forms of wealth other than the current period wage. Denoting utility by $U(\cdot)$ where $U' > 0$, $U'' < 0$ we can write the firm's expected utility constraint as follows:

$$\sum_i \sum_j \rho_i q_j U(W_{ij}) + \beta \sum_i \sum_j \sum_k \rho_i q_j q_k U(\hat{W}_{ijk}) > \bar{U} \quad (3.2)$$

Bankruptcy Constraints

If we were to solve the maximization problem as it stands, i.e., maximize (3.1) subject to (3.2), the solution would trivially call for a fixed wage payment over both time periods and over all states of nature. In order to induce wage movements in this model we examine the behavior of the firm when it faces binding bankruptcy constraints.

This is not to suggest that wage movements will occur only in firms facing bankruptcy. It is more realistic to think that there is some portion of the firm's assets which are illiquid. Large negative disturbances to the firm's revenue function forces the firm to provide less than perfect insurance to its workers rather than liquidate its assets. For the problem at hand we set the value of the firm's illiquid assets equal to zero.

In the one period implicit contract models with bankruptcy constraints exemplified by Kahn and Scheinkman (1985) and Farmer (1985), the firm is constrained from earning negative profits in any state of nature. In the model presented here we wish to allow the firm to borrow and save. For example, the firm may earn a negative profit in period 1 and still insure the worker by borrowing from expected period 2 profits. Alternatively, the firm may earn a positive profit in period 1 and save part or all of it to pay off expected period 2 losses. This necessitates the use of two bankruptcy constraints. The first constrains the firm's expected net worth after the realization of the period 1 state of nature. The second constrains the firm's actual net worth after the realization of the period 2 state of nature.

The first constraint is called the conditional bankruptcy constraint. We allow the firm to borrow or save as long as its expected net worth contingent on the period 1 state of nature is nonnegative. We write this constraint as follows:

$$Y_{ij} - W_{ij} + \beta \sum_{k} q_k(\hat{Y}_{ik} - \hat{W}_{ijk}) \geq 0 \text{ for all } i, j. \qquad (3.3)$$

The second constraint is called the solvency constraint. This constraint restricts the firm to have a nonnegative net worth after the period 2 state of nature is realized. If the firm earns a positive profit in period 1 then it cannot experience a loss in period 2 which exceeds its period 1 savings. For any i, j, k such that period 1 profits are positive, the firm faces the following constraint:

$$Y_{ij} - W_{ij} + \beta(\hat{Y}_{ik} - \hat{W}_{ijk}) > 0. \tag{3.4a}$$

This is simply the two period analog of the bankruptcy constraint found in the one period contracting models. This constraint is overly restrictive for a two period model, however. Consider what happens when the firm experiences a period 1 loss. If the firm borrows against period 2 expected profits but finds that the realized shock in period 2 is such that it cannot pay off the loan then it must simply forfeit all output to the worker and default on the loan. For the case of a period 1 loss (3.4a), is not the relevant constraint. Instead we simply have

$$\hat{Y}_{ik} - \hat{W}_{ijk} > 0. \tag{3.4b}$$

The solvency constraint effectively makes the firm the residual claimant, that is, the worker is paid, then the creditor. If anything is left over after that it goes to the firm.

Combining (3.4a) and (3.4b) into a single constraint we have the following:

$$\beta(\hat{Y}_{ik} - \hat{W}_{ijk}) + \max(Y_{ij} - W_{ij}, 0) > 0 \quad \text{for all } i, j, k. \tag{3.5}$$

<u>The Optimal Contract</u>

Formally, the firm's objective is to maximize (3.1) subject to constraints (3.2), (3.3) and (3.5). Since the full Lagrangian function is quite cumbersome it has been relegated to Appendix 4. We denote the Lagrangian multiplier on constraint (3.2) by λ, the set of Lagrangian multipliers associated with constraints (3.3) by $\{\phi_{ij}\}$ and the set of Lagrangian multipliers associated with constraints (3.5) by $\{\gamma_{ijk}\}$. The first order conditions for profit maximization lead to the following expressions:

$$\lambda U'(W_{ij}) = \frac{\phi_{ij} + \sum_k \gamma_{ijk}}{\rho_i q_j} + 1, \tag{3.6a}$$

for i, j such that $\max(Y_{ij} - W_{ij}, 0) = Y_{ij} - W_{ij}$,

$$\lambda U'(W_{ij}) = \frac{\phi_{ij}}{\rho_i q_j} + 1, \tag{3.6b}$$

for i, j such that $\max(Y_{ij} - W_{ij}, 0) = 0$,

$$\lambda U'(\hat{W}_{ijk}) = \frac{\phi_{ij} q_k + \gamma_{ijk}}{\rho_i q_j q_k} + 1, \tag{3.7}$$

for all i, j, k,

$$\sum_i \sum_j \rho_i q_j U(W_{ij}) + \beta \sum_i \sum_j \sum_k \rho_i q_j q_k U(\hat{W}_{ijk}) - \bar{U} > 0, \tag{3.8}$$

with equality if $\lambda > 0$.

$$Y_{ij} - W_{ij} + \beta \sum_k q_k(\hat{Y}_{ik} - \hat{W}_{ijk}) \geq 0 \qquad (3.9)$$

for all i, j with equality if $\phi_{ij} > 0$,

$$\beta(\hat{Y}_{ik} - \hat{W}_{ijk}) + \max(Y_{ij} - W_{ij}, 0) \geq 0 \qquad (3.10)$$

for all i, j, k with equality if $\gamma_{ijk} > 0$.

Given our assumptions on the utility and profit functions, expressions (3.6a), (3.6b)-(3.10) fully characterize the profit maximizing wage contract. Our strategy for the remainder of this section will be to analyze the various cases where conditions (3.9) and (3.10) hold with equality and inequality and investigate the implications for the behavior of the real wage. Since profits are strictly decreasing in W, (3.8) holds with equality and λ is positive. In addition, we assume that the states of nature are ordered so that $\nu_1 < \nu_2 < \dots < \nu_M$, $\varepsilon_1 < \varepsilon_2 \dots < \varepsilon_N$ and $\hat{\varepsilon}_1 < \hat{\varepsilon}_2 < \dots < \hat{\varepsilon}_N$.

Case (i): constraints (3.3) and (3.5) are not binding. If we assume that (3.9) and (3.10) hold with strict inequality then conditions (3.6) and (3.7) imply the following:

$$U'(W_{ij}) = U'(\hat{W}_{ijk}).$$

This is the usual full insurance condition when firms are risk neutral and workers are risk averse. The optimal contract in this case calls for a state invariant wage payment.

Case (ii): constraint (3.3) is binding for some i, j. Period 1 profits are positive and therefore constraint (3.5) is binding for some k. If constraint (3.3) is binding for some i, j we may rewrite (3.9) as follows:

$$Y_{ij} - W_{ij} = -\beta \sum_k q_k(Y_{ik} - \hat{W}_{ijk}).$$

Given that first period profits are positive, it follows that the expected value of second period profits conditional on first period information is negative and large enough in magnitude to bind constraint (3.3). This necessarily implies that there is at least one realization of $\hat{\varepsilon}_k$ which binds constraint (3.5). Since our states of nature are ordered from low to high we may arbitrarily pick $k = \bar{k}$ to be the state for which all $\hat{\varepsilon}_k$ for $k < \bar{k}$ cause (3.5) to be binding.

Rewriting first order conditions (3.6a) and (3.7) for this case yields the following:

$$\lambda U'(W_{ij}) = \frac{\phi_{ij} + \sum_{k=1}^{\bar{k}} \gamma_{ijk}}{\rho_i q_j} + 1, \qquad (3.11)$$

$$\lambda U'(\hat{W}_{ijk}) = \frac{\phi_{ij} q_k + \gamma_{ijk}}{\rho_i q_j q_k} + 1, \qquad \text{for } k < \bar{k} \qquad (3.12)$$

$$\lambda U'(\hat{W}_{ijk}) = \frac{\phi_{ij}}{\rho_i q_j} + 1 \qquad \text{for } k = \bar{k}+1,\ldots,N \qquad (3.13)$$

The first thing to notice here is that the wage is state dependent in both time periods. The firm attempts to smooth the worker's income over time and across states of nature. If, for a particular realization of i,j, there is some value of $\bar{k}$ for which $k < \bar{k}$ causes (3.5) to be binding, the firm will attempt to save against this event. This is indicated by the presence of $\sum_{k=1}^{k} \gamma_{ijk}$ in expression (3.11). If $k > \bar{k}$ occurs in period 2 then the firm will increase the wage payment but the size of the increase will be independent of the actual realization of $\hat{\varepsilon}_k$. Another way to interpret this is that the firm insures the worker against all temporary shocks in period 2 except for the temporary shocks $\hat{\varepsilon}_k$, $k < \bar{k}$. If $\hat{\varepsilon}_k$, $k < \bar{k}$ occurs the firm must lower the wage to $\hat{W}_{ijk}$. We may therefore define $\hat{W}_{ijk} = \tilde{W}_{ij}$ for $k = \bar{k} + 1,\ldots N$.

Making use of this simplification we may solve (3.11), (3.12) and (3.13) yield the following expression:

$$U'(W_{ij}) = \sum_{k=1}^{\bar{k}} q_k U'(\hat{W}_{ijk}) + \left(1 - \sum_{k=1}^{\bar{k}} q_k\right) U'(\tilde{W}_{ij}), \qquad (3.14)$$

which says that even though the firm cannot insure the worker against fluctuations in the marginal utility of consumption, the optimal contract does call for insuring the worker against fluctuations in the <u>expected</u> marginal utility of consumption.

The empirically interesting implication of this model can be seen by examining the response of the first period wage to changes in the permanent and temporary shocks. Conditions (3.9), (3.10) and (3.14) may be solved to yield the following partial derivatives:

$$\frac{\partial W_{ij}}{\partial \nu_i} = \frac{1 + \beta}{1 + \beta\Delta} \qquad (3.15)$$

$$\frac{\partial W_{ij}}{\partial \varepsilon_j} = \frac{1}{1 + \beta\Delta}, \qquad (3.16)$$

where $\Delta = U''(W_{ij}) / \sum_{k=1}^{\bar{k}} q_k U''(\hat{W}_{ijk}) + (1 - \sum_{k=1}^{\bar{k}} q_k) U''(\tilde{W}_{ij}) > 0.$

Expressions (3.15) and (3.16) show the asymmetric response of the real wage to permanent and temporary shocks. The intuition behind this result is simple. Since the firm is interested in smoothing the worker's wage income across states of nature, it will save part of the increase in ε_j in order to augment the second period wage. There is no need for the firm to save part of the increase in the permanent shock since the permanent shock in period 2 will take on the same value as the period 1 permanent shock.

The important comparison to be made here is with the behavior of the real wage in a spot market model where risk shifting is not occurring. In such a model the firm takes the real wage as given each time period and then chooses a quantity of labor which equates the real wage to the marginal product of labor. Any disturbance to the marginal product of labor will cause the real wage to change by the full change in the marginal product regardless of how persistent the disturbance is expected to be. In other words, the real wage in a spot market for labor will respond by the same amount to permanent and temporary revenue function disturbances.

The size of the real wage response to a given change in ν_i or ε_j depends upon β. Differentiating (3.15) and (3.16) with respect to β we have the following:

$$\frac{\partial^2 W_{ij}}{\partial \nu_i \partial \beta} = \frac{1 - \Delta}{(1 + \beta\Delta)^2} \gtreqless 0 \text{ as } \Delta \lesseqgtr 1, \tag{3.17}$$

$$\frac{\partial^2 W_{ij}}{\partial \varepsilon_j \partial \beta} = \frac{-\Delta}{(1 + \beta\Delta)^2} < 0. \tag{3.18}$$

The interpretation of (3.18) is straightforward. Recall that the firm is saving from first period profits in order to augment the second period wage. For a given increase in ε_j, the size of the increase in the firm's wealth is positively related to the real interest rate. The response of the wage to a change in the temporary shock is therefore positively related to the real interest rate.

The sign on (3.17) is ambiguous. In order to determine the magnitude of Δ we need to know whether U'' is concave or convex. This would require us to make an assumption about the fourth derivative of the utility function.

Case (iii): constraint (3.3) is binding for some i, j and constraint (3.5) is not binding for all k. Period 1 profits are negative.

In this case the firm experiences a loss in period 1 and the conditional expectation of period 2 profits is positive but not great enough to give the firm a positive net value over the two periods. Rewriting first order conditions (3.6b) and (3.7) for this case yields the following:

$$U'(W_{ij}) = \frac{\phi_{ij}}{\rho_i q_j} + 1, \tag{3.19a}$$

$$U'(\hat{W}_{ijk}) = \frac{\phi_{ij}}{\rho_i q_j} + 1. \tag{3.19b}$$

In this case the firm offers full insurance across time periods but not across states of nature i and j. The wage is fixed across the two time periods but the level at which it is fixed depends upon the realizations of ν_i and ε_j.

Defining $\bar{W}_{ij} = W_{ij} = \hat{W}_{ijk}$ we can rewrite (3.9) as follows:

$$\bar{W}_{ij} = \nu_i + \frac{1}{1 + \beta}\varepsilon_j + \frac{1}{1 + \beta} \sum_k q_k \hat{\varepsilon}_k. \tag{3.20}$$

As in Case (ii) the wage responds asymmetrically to changes in permanent and temporary shocks. Again, the magnitude of the effect of a change in ε_j on the real wage is positively related to the real interest rate. The same intuition applies.

In order to cover all of the possible cases we need to examine what happens if Case (ii) is changed to allow constraint (3.5) to become binding for $k < \bar{k}$. Rewriting first order conditions (3.6b) and (3.7) for this case yields the following:

$$\lambda U'(W_{ij}) = \frac{\phi_{ij}}{\rho_i q_i} + 1, \tag{3.21}$$

$$\lambda U'(\hat{W}_{ijk}) = \frac{\phi_{ij}}{\rho_i q_j q_k} + \frac{\gamma_{ijk}}{\rho_i q_j p_k} + 1, \qquad \text{for } k < \bar{k}, \tag{3.22}$$

$$\lambda U'(\hat{W}_{ijk}) = \frac{\phi_{ij}}{\rho_i q_i} + 1, \qquad \text{for } k = \bar{k} + 1,..,N. \tag{3.23}$$

From (3.23) we know that $\hat{W}_{ijk} = \tilde{W}_{ij}$ for $k = \bar{k} + 1,\ldots,N$. Expressions (3.21), (3.22), (3.23), (3.9) and (3.10) can then be solved for expression (3.20). The implications for the behavior of the first period wage in response to changes in ν_i and ε_j do not change when we allow (3.5) to become binding.

3.3 Empirical Considerations

The above model yields the testable implication that if risk neutral firms are insuring risk averse workers, then the real wage will respond more to a permanent shock than to a temporary shock. This section discusses the empirically relavent distinction between permanent and temporary shocks. The characteristic which distinguishes the permanent from the temporary shock in the model presented above is that the permanent shock persists for two periods while the temporary shock persists for only one. It is the relative persistence of the permanent and temporary shocks which drives the asymmetric response result.

If we extend the planning horizon to $n > 2$ periods, the reduced form expression for the wage in case (iii) becomes the following:

$$W_{ij} = \nu_i + \frac{1}{\sum_{\ell=0}^{n-1}\beta^{\ell}}\varepsilon_j + \frac{1}{\sum_{\ell=0}^{n-1}\beta^{\ell}}\Omega^{n}, \tag{3.24}$$

where Ω^n is the expectation of the sum of the temporary shocks in periods 2 through n conditional on period 1 information. If we allow the temporary shock ε_j to persist for $\bar{n}$ periods, the reduced form expression for the wage becomes the following:

$$\overline{W}_{ij} = \nu_i + \frac{\sum_{\ell=0}^{\overline{n}-1} \beta^{\ell}}{\sum_{\ell=0}^{n-1} \beta^{\ell}} \varepsilon_j + \frac{\sum_{\ell=0}^{\overline{n}-1} \beta^{\ell}}{\sum_{\ell=0}^{n-1} \beta^{\ell}} \Omega^{n}. \tag{3.25}$$

We see from equation (3.25) that for $\overline{n} < n$ the asymmetry result holds.[2] In testing the asymmetric wage response we therefore need to decompose our series on revenue function disturbances into relatively "more persistent" and relatively "less persistent" components. A method for doing this, which decomposes the data into its frequency components, is presented in chapter 4.

A Word on Aggregate Shocks

The model presented above distinguishes between permanent and temporary revenue function disturbances but no mention has been made of how these disturbances are correlated with aggregate shocks. It has been implicitly assumed, however, that the capital market clears at the constant interest rate r, and therefore there are no aggregate shifts in the demand for or supply of capital. If we include an aggregate revenue function disturbance and allow r to become a state variable, we still obtain the asymmetric real wage response result. The absolute magnitude of the real wage response to a permanent or temporary shock will change with the aggregate disturbance but the change due to a permanent shock will always be greater than the change due to a temporary shock.

3.4 Summary and Conclusion

The purpose of this chapter was to demonstrate that risk shifting may be identified by observing the real wage response to permanent and temporary revenue function disturbances. This result was demonstrated in an implicit contract model in which risk neutral firms insure risk averse workers but are constrained by bankruptcy in certain states of nature. It was shown that if risk shifting is occurring then the real wage will respond more to a permanent revenue function disturbance than to a temporary revenue function disturbance.

The relevant distinction between permanent and temporary revenue function disturbances was then shown to be the relative persistence of each. As long as the measured permanent revenue function disturbance is relatively more persistent than the measured temporary disturbance, the asymmetric response result obtains. In the following chapter we develop a measure of permanent and temporary revenue function disturbances which captures this notion of relative persistence. The asymmetric response implication is then tested on industry level data.

FOOTNOTES

[1]Eliminating employment as a choice variable simplifies the analysis considerably. If we assume that utility is separable in consumption and leisure and that the firm adjusts employment discretely (through layoffs and recalls rather than hours adjustment) then the first order conditions for the wage are identical to (3.6a), (3.6b) and (3.7). If we allow the firm to adjust hours the wage rigidity softens somewhat but the same general results obtain.

[2]Expression (3.25) can be generalized further. If we allow the permanent shock ν_i to persist for $n' < n$ periods we have

$$\overline{W}_{ij} = \frac{\sum_{\ell=0}^{n'-1} \beta^{\ell}}{\sum_{\ell=0}^{n-1} \beta^{\ell}} \nu_i + \frac{\sum_{\ell=0}^{\bar{n}-1} \beta^{\ell}}{\sum_{\ell=0}^{n-1} \beta^{\ell}} \varepsilon_j + \frac{\sum_{\ell=0}^{n^*-1} \beta^{\ell}}{\sum_{\ell=0}^{n-1} \beta^{\ell}} \Omega^n,$$

where $n^* = \min(n', \bar{n})$ and Ω^n now equals the expectation of the sum of the permanent and temporary shocks in periods n^* through n.

CHAPTER 4

EMPIRICAL EVIDENCE ON THE REAL WAGE RESPONSE TO PERMANENT AND TEMPORARY SHOCKS

4.1 Introduction

The purpose of this chapter is to test the asymmetric wage response implication of the model presented in Chapter 3. The implication of the model in which risk neutral firms insure risk averse workers is that the real wage will respond more to a permanent shock than to a temporary shock of the same size.

This implication is tested using data from 12 4-digit SIC code industries. The industry output price is used as a proxy for disturbances to the industry revenue function. A stationary transformation of the industry output price is decomposed into permanent and temporary components using a frequency domain technique. The real wage is regressed on each component and the asymmetric wage response is tested by comparing the relative size of the coefficients.

Two separate tests are conducted. The first test involves dividing revenue function disturbances into permanent and temporary components at three frequency splits. The results for this test show that for 7 of the 12 industries sampled there is evidence that the real wage responds more to a permanent shock than to a temporary shock. The second test involves applying a band pass filter which zeroes out the middle third of the frequencies in the revenue function data. For 6 of the 12 industries sampled the results are strengthened as a result of applying the band pass filter. In addition, the industry wage responses are estimated as a system of seemingly unrelated regressions. The joint asymmetric wage response hypothesis is supported at the .01 level of significance.

This chapter is organized as follows. Section 4.2 describes the data used. Section 4.3 describes the technique used for decomposing the data into permanent and temporary components. Section 4.4 presents the empirical results from the test employing three frequency splits. Section 4.5 presents the empirical results from the test employing the band pass filter and the seemingly unrelated regressions. Section 4.6 presents a summary and conclusion.

4.2 The Data

The model presented in Chapter 3 characterizes the behavior of a representative firm and a representative worker. For testing purposes we use industry level data. This aggregation does not present a problem since we can think of the model presented in Chapter 3 as being a characterization of a representative industry and a fixed pool of workers who are attached to the industry. The shocks which we are interested in decomposing into permanent and temporary components then become industry specific shocks.

Our first task is to find a measure of industry specific revenue function disturbances. A natural measure of revenue function disturbances is the value of the average product of labor since it captures both movements in the price of output and changes in the productivity of the worker. In order to construct a measure of industry level average product we need four variables: hours, employment, real output and the price of output. Since the number of industries for which all of these variables can be obtained is small, an alternative measure of revenue function disturbances was chosen, namely, the industry output price. The industry output price is an adequate proxy for revenue function disturbances as long as movements in the output price are positively correlated with revenue. A sufficient condition for this to be true is that the industry price movements are dominated by shifts in the demand for output. A weaker condition is that demand for the industry output is inelastic.

The data are from 12 4-digit SIC code industries. The output price data are from the Department of Commerce's Producer Price Index. The wage data are from the Bureau of Labor Statistics' Employment, Hours, and Earnings survey. Both the industry output price data and the industry wage data are deflated by the consumer price index. All series are non-seasonally adjusted. Observations are monthly and the sample period is from February 1967 through January 1982.

4.3 Decomposition of Data into Permanent and Temporary Components

The characteristic which distinguishes the permanent shock from the temporary shock in the model presented in Chapter 3 is that the permanent shock persists for two periods while the temporary shock persists for only one. Roughly speaking, we must therefore decompose our output price data into relatively "more persistent" and relatively "less persistent" components.

The technique employed here is to decompose the data into its frequency components. We then associate the long frequency components with the more persistent movements in the data and the short frequency components with the temporary or less persistent movements in the data.[1] Since the asymmetric wage response result depends upon only the relative persistence of the two components, the result should hold for any arbitrary frequency cut-off.

We begin by first differencing the natural log of the output price and real wage data for each of the 12 industries in order to obtain stationary series.[2] Since the data for each industry are treated the same we will denote the first difference of the natural log of the output price and real wage by $DlnP_t$ and $DlnW_t$ respectively, omitting an industry subscript.

The next step involves computing the discrete Fourier transform of $DlnP_t$ (see Bloomfield, 1976, pp. 46-49):

$$J(\omega_j) = \frac{1}{N}\sum_{t=0}^{N-1} DlnP_t \exp(-i\omega_j t), \quad j = 0,\ldots,N-1, \qquad (4.1)$$

where N is the total number of data points in the $DlnP_t$ series and $\omega_j = \frac{2\pi j}{N}$ denotes the Fourier frequency. We recover the original series by computing the inverse transform:

$$DlnP_t = \sum_{j=-N/2+1}^{N/2} J(\omega_j)\exp(i\omega_j t), \quad t = 0,\ldots,N-1. \qquad (4.2)$$

Since $\exp(i\omega_j t) = \cos(\omega_j t) + i\sin(\omega_j t)$, expression (4.2) shows that the $DlnP_t$ series may be written as the sum of N cosine and sine functions, each with a different frequency. The power associated with each frequency component is given by the Fourier coefficient $J(\omega_j)$. For example, the first term in the summation is:

$$J(\omega_0)[\cos(\omega_0 t) + i\sin(\omega_0 t)] = J(\omega_0)t,$$

which, when summed over t, measures the mean of the $DlnP_t$ series. The frequency one term in the summation is:

$$J(\omega_1)[\cos\omega_1 t + i\sin\omega_1 t] + J(\omega_{-1})[\cos\omega_{-1}t + i\sin\omega_{-1}t],$$

which captures the portion of $DlnP_t$ which goes through one full cycle over the entire sample period. When this term is positive it tends to remain positive for several time periods and when it is negative it tends to remain negative for several time periods. Since we are stepping through the sine and cosine functions by rather small increments of $2\pi/N$, the magnitude of $\cos\omega_1 t + i\sin\omega_1 t$ will change very little from time period to time period. This provides the intuition behind associating the long frequency components of $DlnP_t$ with the relatively more persistent part of the variable.

The short frequency terms in expression (4.2) provide us with the temporary movements in $DlnP_t$. If we consider the last term in the summation:

$$J(\omega_{N/2})[\cos(\omega_{N/2}t) + i\sin(\omega_{N/2}t)],$$

we can see that this captures the portion of $DlnP_t$ which goes through 1/2 full cycle every time period.[3]

The asymmetric wage response depends upon only the relative persistence of the permanent and temporary components. We therefore choose an arbitrary frequency to divide $DlnP_t$ into its long frequency component and its short frequency component. Denoting this frequency by ω_c where ω_c in an integer in the interval (0,N/2), we may write:[4]

$$DlnP_t^P = \sum_{j=-c}^{c} J(\omega_j)\exp(i\omega_j t), \qquad t = 0,\ldots,N-1, \tag{4.3}$$

$$DlnP_t^T = \sum_{j=-N/2+1}^{-c+1} J(\omega_j)\exp(i\omega_j t) + \sum_{j=c+1}^{N/2} J(\omega_j)\exp(i\omega_j t), \tag{4.4}$$

$$t = 0,\ldots,N-1,$$

where $DlnP_t^P$ denotes the permanent component and $DlnP_t^T$ denotes the temporary component of the industry output price series.

In the first set of empirical tests (presented in Section 4.4) 3 frequency splits are employed: $\omega_c = 2\pi/3$, $2\pi/6$ and $2\pi/12$. Since we are dealing with monthly data a frequency of $2\pi/3$ corresponds to a period of 3 months. When $\omega_c = 2\pi/3$, any portion of the data which goes through a full cycle in 3 months or less is included in the temporary component while any portion of the data which goes through a full cycle in a period longer than 3 months is included in the permanent component. Similarly, $2\pi/6$ and $2\pi/12$ correspond to periods of 6 and 12 months, respectively.

In the second set of empirical tests (presented in Section 4.5) a band pass filter is applied to $DlnP_t$ prior to dividing it into its permanent and temporary components. The band pass filter is designed to eliminate the middle third of the periodogram of $DlnP_t$. The bottom third is then inverse transformed to obtain the permanent component and the top third is inverse transformed to obtain the temporary component.

4.4 Empirical Results Employing Three Frequency Splits

The asymmetric wage response was tested by running the following regression:

$$DlnW_t = \alpha + \beta^P DlnP_t^P + \beta^T DlnP_t^T + \mu_t \qquad (4.5)$$

where μ_t is an error term. The t-statistic for the null hypothesis that $\beta^P - \beta^T = 0$ was constructed. Rejecting the null in favor of the alternative hypothesis that $\beta^P - \beta^T > 0$ supports the asymmetric wage response implication of the model.

Efficient estimators for α, β^P and β^T requires that μ_t is serially uncorrelated. In addition, since we are interested in tests of significance we wish to have unbiased estimates of the standard errors. If serial correlation is present the estimated standard errors are biased. Since our data are monthly and since there are likely to be other factors influencing the behavior of the real wage which we have not modelled, we expect μ_t to be serially correlated.

We assume that μ_t is an autoregressive process of order p which may be written as:

$$\mu_t = z_t - r_1\mu_{t-1} - \cdots - r_p\mu_{t-p},$$

where z_t is normally and independently distributed, and r_i, $i = 1,\ldots,p$ is the i^{th} autoregressive parameter. A two stage generalized least squares procedure is then used to estimate α, β^P, and β^T. In the first stage the ordinary least squares estimates are calculated and the autoregressive parameters are estimated from the regression residuals. The parameters α, β^P and β^T are then reestimated using generalized least squares. The resulting parameter estimates are asymptotically efficient and the estimated standard errors are unbiased (See Kementa, 1971, pp. 269-297).

Tables (4.1) through (4.12) present the test results. Standard errors are in parentheses below the parameter estimates. Levels of significance are presented below the t-statistics. To measure serial correlation in the residuals the Ljung-Box Q-statistic is calculated (see Ljung and Box (1978)). Denoting the k^{th} estimated autocorrelation coefficient by $\hat{r}_k$, Ljung and Box have shown that the quantity

$$Q(\hat{r}) = N(N + 2) \sum_{k=1}^{m} \hat{r}_k^2/(N - k),$$

where N is the sample size, approximately follows a chi-square distribution with m degrees of freedom under the null hypothesis that the sum of the squares of the first m autocorrelation coefficients is equal to zero. The tables present this statistic for m = 12. The number in parentheses below the Ljung-Box Q-statistic is the probability of incorrectly rejecting the null hypothesis.

The first thing to note from these tables is that the t-statistics are sensitive to the frequency cut-off. With the exception of "Sausages and Other Prepared Meats," the estimated standard errors are negatively related to the band width of frequencies included in the variable. This makes sense since the larger the band width the more information contained in the variable and therefore the lower the estimated standard error. The implication of this however, is that although the asymmetric response result should theoretically hold for any arbitrary frequency cut-off, empirically this is not possible since accurate estimates cannot be made if the amount of information contained in the variable is small.

The strongest asymmetric response results appear in the following industries: "Glass Containers," "Motors and Generators," and "Mens' and Boys' Separate Trousers." In the "Glass Containers" industry the t-statistic for the $H_0 : \beta^P - \beta^T = 0$ is significant for all 3 frequency cut-offs and, both the permanent and temporary components are significantly different from zero for the $2\pi/12$ cut-off.

In "Mens' and Boys' Separate Trousers," the t-statistic for the $H_0 : \beta^P - \beta^T = 0$ is significant for the $2\pi/6$ and $2\pi/12$ cut-off and, at the $2\pi/12$ cut-off, both coefficients are significantly different from zero. For "Motors and Generators," the t-statistic for the $H_0 : \beta^P - \beta^T = 0$ is significant at the $2\pi/3$ and $2\pi/12$ split and marginally significant at the $2\pi/6$ split.

The two primary metal industries: "Primary Aluminum," and "Blast Furnaces and Steel Mills," show the correct signs and magnitudes but the t-statistic for the $H_0 : \beta^P - \beta^T = 0$ fails to be significant for all frequency cut-offs.

Table 4.13 groups the industries into two categories: those which show a significant asymmetric wage response at one or more frequency cut-offs and those which fail to show a significant asymmetric wage response for all frequency cut-offs. The following is a detailed summary of the results contained in Tables 4.1-4.12.

<u>Summary of Tables 4.1-4.12</u>

For the frequency split $2\pi/3$, eleven out of the twelve industries sampled show an estimated coefficient for β^P which is larger than the estimated coefficient for β^T. Constructing the test statistic for the

TABLE 4.1: Internal Combustion Engines

<u>Sample Period</u>: 1967:02-1982:01 <u>SIC</u>: 3519

Frequency Split		β^P	β^T	T for H_0: $\beta^P-\beta^T = 0$	R^2	Ljung-Box Q at 12 lags
Permanent	Temporary					
$0 \le \omega_j < 2\pi/3$	$2\pi/3 \le \omega_j \le \pi$	.356 (.10)	-.078 (.24)	1.68 (.05)	.17	5.61 (.935)
$0 \le \omega_j < 2\pi/6$	$2\pi/6 \le \omega_j \le \pi$	.360 (.11)	.09 (.18)	1.19 (.11)	.17	5.17 (.952)
$0 \le \omega_j < 2\pi/12$	$2\pi/12 \le \omega_j \le \pi$	.32 (.13)	.28 (.14)	.21 (.42)	.17	4.71 (.967)

TABLE 4.2: Blast Furnaces and Steel Mills

Sample Period: 1967:02-1982:01 SIC: 3312

Frequency Split		β^P	β^T	T for H_0: $\beta^P - \beta^T = 0$	R^2	Ljung-Box Q at 12 lags
Permanent	Temporary					
$0 \leq \omega_j < 2\pi/3$	$2\pi/3 \leq \omega_j \leq \pi$	.28 (.06)	.15 (.17)	.72 (.24)	.28	3.19 (.994)
$0 \leq \omega_j < 2\pi/6$	$2\pi/6 \leq \omega_j \leq \pi$	.26 (.06)	.22 (.13)	.28 (.39)	.28	3.15 (.994)
$0 \leq \omega_j < 2\pi/12$	$2\pi/12 \leq \omega_j \leq \pi$	.26 (.07)	.25 (.10)	.08 (.47)	.28	3.32 (.993)

TABLE 4.3: Primary Aluminum

<u>Sample Period</u>: 1967:02-1982:01 <u>SIC</u>: 3334

Frequency Split		β^P	β^T	T for H_0: $\beta^P-\beta^T = 0$	R^2	Lung-Box Q at 12 lags
Permanent	Temporary					
$0 < \omega_j < 2\pi/3$	$2\pi/3 < \omega_j < \pi$	.075 (.055)	.034 (.135)	.28 (.39)	.25	2.46 (.998)
$0 < \omega_j < 2\pi/6$	$2\pi/6 < \omega_j < \pi$	.10 (.06)	.008 (.08)	.92 (.18)	.26	2.24 (.994)
$0 < \omega_j < 2\pi/12$	$2\pi/12 < \omega_j < \pi$	.09 (.07)	.04 (.07)	.46 (.32)	.25	2.40 (.998)

TABLE 4.4: Motors and Generators

Sample Period: 1967:02-1982:01 SIC: 3621

Frequency Split		β^P	β^T	T for H_0: $\beta^P - \beta^T = 0$	R^2	Ljung-Box Q at 12 lags
Permanent	Temporary					
$0 < \omega_j < 2\pi/3$	$2\pi/3 < \omega_j < \pi$	.32 (.10)	-.15 (.17)	2.43 (.008)	.14	5.98 (.917)
$0 < \omega_j < 2\pi/6$	$2\pi/6 < \omega_j < \pi$	.29 (.10)	.08 (.14)	1.23 (.11)	.13	4.61 (.970)
$0 < \omega_j < 2\pi/12$	$2\pi/12 < \omega_j < \pi$	.34 (.11)	.12 (.12)	1.36 (.09)	.14	5.33 (.946)

TABLE 4.5: Printing Trades Machinery

Sample Period: 1967:02-1982:01 SIC: 3555

Frequency Split		β^P	β^T	T for H_0: $\beta^P-\beta^T = 0$	R^2	Ljung-Box Q at 12 lags
Permanent	Temporary					
$0 < \omega_j < 2\pi/3$	$2\pi/3 < \omega_j < \pi$	.14 (.11)	.09 (.17)	.25 (.40)	.15	2.87 (.996)
$0 < \omega_j < 2\pi/6$	$2\pi/6 < \omega_j < \pi$	.16 (.13)	.09 (.12)	.39 (.35)	.15	2.77 (.997)
$0 < \omega_j < 2\pi/12$	$2\pi/12 < \omega_j < \pi$	.24 (.21)	.10 (.10)	.60 (.27)	.15	2.57 (.998)

TABLE 4.6: Electric Lamps

Sample Period: 1967:02-1982:01 **SIC:** 3641

Frequency Split		β^P	β^T	T for H_0: $\beta^P - \beta^T = 0$	R^2	Ljung-Box Q at 12 lags
Permanent	Temporary					
$0 \leq \omega_j < 2\pi/3$	$2\pi/3 \leq \omega_j \leq \pi$	.19 (.07)	-.09 (.12)	1.99 (.02)	.13	5.86 (.923)
$0 \leq \omega_j < 2\pi/6$	$2\pi/6 \leq \omega_j \leq \pi$	.20 (.08)	.06 (.09)	1.27 (.10)	.13	6.01 (.916)
$0 \leq \omega_j < 2\pi/12$	$2\pi/12 \leq \omega_j \leq \pi$	.21 (.12)	.12 (.07)	.66 (.26)	.12	8.92 (.710)

TABLE 4.7: Transformers

Sample Period: 1967:02-1982:01 **SIC:** 3612

Frequency Split		β^P	β^T	T for H_0: $\beta^P-\beta^T = 0$	R^2	Ljung-Box Q at 12 lags
Permanent	Temporary					
$0 \leq \omega_j < 2\pi/3$	$2\pi/3 \leq \omega_j \leq \pi$	.24 (.07)	-.001 (.14)	1.53 (.06)	.10	4.13 (.981)
$0 \leq \omega_j < 2\pi/6$	$2\pi/6 \leq \omega_j \leq \pi$	.26 (.08)	.06 (.11)	1.48 (.07)	.10	3.77 (.987)
$0 \leq \omega_j < 2\pi/12$	$2\pi/12 \leq \omega_j \leq \pi$	.26 (.09)	.11 (.09)	1.15 (.13)	.09	3.31 (.993)

TABLE 4.8: Glass Containers

Sample Period: 1967:02-1982:01 | SIC: 3221

Frequency Split		β^P	β^T	T for H_0: $\beta^P - \beta^T = 0$	R^2	Ljung-Box Q at 12 lags
Permanent	Temporary					
$0 \leq \omega_j < 2\pi/3$	$2\pi/3 \leq \omega_j \leq \pi$	.30 (.07)	-.08 (.14)	2.52 (.01)	.30	3.98 (.984)
$0 \leq \omega_j < 2\pi/6$	$2\pi/6 \leq \omega_j \leq \pi$	.49 (.09)	.05 (.08)	3.65 (.001)	.32	4.79 (.965)
$0 \leq \omega_j < 2\pi/12$	$2\pi/12 \leq \omega_j \leq \pi$	.50 (.13)	.14 (.06)	2.58 (.005)	.31	3.06 (.995)

TABLE 4.9: Mens' and Boys' Separate Trousers

Sample Period: 1967:02-1982:01 SIC: 2327

Frequency Split		β^P	β^T	T for H_0: $\beta^P - \beta^T = 0$	R^2	Ljung-Box Q at 12 lags
Permanent	Temporary					
$0 \leq \omega_j < 2\pi/3$	$2\pi/3 \leq \omega_j \leq \pi$	.18 (.07)	.14 (.20)	.19 (.42)	.27	5.83 (.925)
$0 \leq \omega_j < 2\pi/6$	$2\pi/6 \leq \omega_j \leq \pi$	.35 (.13)	.08 (.09)	1.70 (.05)	.30	5.46 (.941)
$0 \leq \omega_j < 2\pi/12$	$2\pi/12 \leq \omega_j \leq \pi$	.37 (.17)	.13 (.08)	1.27 (.10)	.30	4.30 (.977)

TABLE 4.10: Metal Cans

Sample Period: 1967:02-1982:01 SIC: 3411

Frequency Split		β^P	β^T	T for H_0: $\beta^P-\beta^T = 0$	R^2	Ljung-Box Q at 12 lags
Permanent	Temporary					
$0 < \omega_j < 2\pi/3$	$2\pi/3 < \omega_j < \pi$	.16 (.05)	-.28 (.12)	3.38 (.0004)	.24	5.53 (.938)
$0 < \omega_j < 2\pi/6$	$2\pi/6 < \omega_j < \pi$	.19 (.08)	.03 (.06)	1.60 (.06)	.20	7.10 (.851)
$0 < \omega_j < 2\pi/12$	$2\pi/12 < \omega_j < \pi$	.18 (.09)	.07 (.06)	1.12 (.13)	.25	4.61 (.970)

TABLE 4.11: Metal Doors, Sash and Trim

Sample Period: 1967:02-1982:01 SIC: 3442

Frequency Split		β^P	β^T	T for H_0: $\beta^P - \beta^T = 0$	R^2	Ljung-Box Q at 12 lags
Permanent	Temporary					
$0 < \omega_j < 2\pi/3$	$2\pi/3 < \omega_j < \pi$	.31 (.08)	.06 (.19)	1.22 (.11)	.25	4.60 (.970)
$0 < \omega_j < 2\pi/6$	$2\pi/6 < \omega_j < \pi$	.31 (.10)	.23 (.10)	.55 (.29)	.25	5.37 (.945)
$0 < \omega_j < 2\pi/12$	$2\pi/12 < \omega_j < \pi$	.35 (.10)	.27 (.09)	.61 (.27)	.27	1.86 (1.00)

TABLE 4.12: Sausages and Other Prepared Meats

Sample Period: 1967:02-1982:01 SIC: 2013

Frequency Split		β^P	β^T	T for H_0: $\beta^P-\beta^T = 0$	R^2	Ljung-Box Q at 12 lags
Permanent	Temporary					
$0 \leq \omega_j < 2\pi/3$	$2\pi/3 \leq \omega_j \leq \pi$	-.02 (.02)	-.003 (.03)	-.49 (.69)	.20	6.72 (.876)
$0 \leq \omega_j < 2\pi/6$	$2\pi/6 \leq \omega_j \leq \pi$	-.03 (.02)	-.003 (.02)	-.90 (.82)	.21	7.02 (.856)
$0 \leq \omega_j < 2\pi/12$	$2\pi/12 \leq \omega_j \leq \pi$	-.02 (.03)	-.012 (.081)	-.23 (.59)	.21	6.78 (.872)

TABLE 4.13: Summary of Significance Levels for Tables 4.1-4.12

Industries which reject $H_0 : \beta^P - \beta^T = 0$ in favor of $\beta^P - \beta^T > 0$ at one or more frequency cut-offs:

Industry	Significance level at frequency split: $2\pi/3$	$2\pi/6$	$2\pi/12$
Internal Combustion Engines	.05	.11	.42
Electric Lamps	.02	.10	.26
Transformers	.06	.07	.13
Metal Cans	.0004	.06	.13
Motors and Generators	.008	.11	.09
Mens' and Boys' Separate Trousers	.42	.05	.10
Glass Containers	.01	.001	.005

Industries which fail to reject $H_0 : \beta^P - \beta^T = 0$ in favor of $\beta^P - \beta^T > 0$ at all frequency cut-offs:

Industry	Significance level at frequency split: $2\pi/3$	$2\pi/6$	$2\pi/12$
Printing Trades Machinery	.40	.35	.27
Blast Furnaces and Steel Mills	.24	.39	.47
Primary Aluminum	.39	.18	.32
Metal Doors, Sash and Trim	.11	.29	.27
Sausages and Other Prepared Meats	.69	.82	.59

null hypothesis that $\beta^P - \beta^T = 0$, the following industries reject in favor of $\beta^P - \beta^T > 0$ at the .05 level of significance: "Internal Combustion Engines," "Motors and Generators," "Electric Lamps," "Glass Containers," and "Metal Cans." At the .1 level of significance the null is rejected for the "Transformers" industry.

For the frequency split $2\pi/6$, eleven out of the twelve industries sampled show an estimated coefficient for β^P which is larger than the estimated coefficient for β^T. The following industries reject the null that $\beta^P - \beta^T = 0$ at the .05 level of significance: "Motors and Generators," "Glass Containers," and "Mens' and Boys' Seperate Trousers." At the .1 level of significance the following industries reject the null that $\beta^P - \beta^T = 0$: "Electric Lamps," "Transformers," and "Metal Cans.

For the frequency split $2\pi/12$, eleven out of the twelve industries sampled show an estimated coefficient for β^P which is larger than the estimated coefficient for β^T. The Glass Containers industry rejects the null that $\beta^P - \beta^T = 0$ at the .05 level of significance. At the .1 level of significance the null is rejected for the "Motors and Generators," and "Mens' and Boys' Seperate Trousers" industries.

4.5 Empirical Results Employing a Band Pass Filter

The results presented in Section 4.4 seem to indicate that while the asymmetric response seems to be present in eleven of the twelve industries sampled, the t-statistics are generally weak and, in fact, only seven of the twelve industries reject the null hypothesis that $\beta^P = \beta^T$ at the .1 level of significance or above.

To improve the power of the t-test a band pass filter is applied to $DlnP_t$ prior to splitting it into its permanent and temporary components. The theoretical justification for this comes from looking at the general wage response equation (from footnote 2, page 45):

$$\overline{W}_{ij} = \frac{\sum_{\ell=0}^{n'-1} \beta^{\ell}}{\sum_{\ell=0}^{n-1} \beta^{\ell}} \nu_i + \frac{\sum_{\ell=0}^{\overline{n}-1} \beta^{\ell}}{\sum_{\ell=0}^{n-1} \beta^{\ell}} \varepsilon_j + \frac{\sum_{\ell=0}^{n^*-1} \beta^{\ell}}{\sum_{\ell=0}^{n-1} \beta^{\ell}} \Omega^n$$

where n' is the number of time periods through which the permanent component (ν_i) persists, and $\overline{n}$ is the number of time periods through which the temporary component (ε_j) persists. The closer n' is to $\overline{n}$, the closer in value will be the coefficients on ν_i and ε_j. By eliminating the middle frequencies from $DlnP_t$ we eliminate the portion of revenue which cause very nearly the same response in the real wage; i.e., we force a gap betwen n' and $\overline{n}$.

The first step in applying this filter involves calculating the periodogram which is defined as follows:

$$I(\omega_j) \equiv \frac{N}{2\pi} J(\omega_j)J^*(\omega_j), \quad j = 0,\ldots,N-1$$

where $J(\omega_j)$ is the fourier coefficient associated with frequency ω_j and $J^*(\omega_j)$ is its complex conjugate. The periodogram ordinate $I(\omega_j)$ is therefore real.

Next we sum the periodogram ordinates over all frequencies and divide by 3:

$$\sum_{j=0}^{N-1} I(\omega_j)/3.$$

For each $DlnP_t$ series, a lower frequency bound denoted by ω_ℓ is chosen such that

$$\sum_{j=0}^{\ell} I(\omega_j) = \sum_{j=0}^{N-1} I(\omega_j)/3,$$

and an upper frequency bound denoted by ω_μ is chosen such that

$$\sum_{j=\mu}^{N-1} I(\omega_j) = \sum_{j=0}^{N-1} I(\omega_j)/3.$$

The frequencies less than and equal to ω_ℓ are retained and inverse Fourier transformed to become the permanent component:

$$DlnP_t^P = \sum_{j=0}^{\ell} J(\omega_j)\exp(i\omega_j t), \quad t = 0,\ldots,N-1.$$

The frequencies greater than and equal to ω_μ are retained and inverse Fourier transformed to become the temporary component:

$$DlnP_t^T = \sum_{j=-N/2+1}^{-\mu} J(\omega_j)\exp(i\omega_j t) + \sum_{j=\mu}^{N/2} J(\omega_j)\exp(i\omega_j t),$$

$$t = 0,\ldots,N-1.$$

For frequencies $\omega_\ell < |\omega_j| < \omega_\mu$, $J(\omega_j) = 0$.

To illustrate the application of this filter to the $DlnP_t$ series the periodograms are presented in Appendix 5. For each industry the frequencies ω_ℓ and ω_μ are plotted on the horizontal axis. The periodogram ordinates between ω_ℓ and ω_μ are equal to zero after the application of the band pass filter.

The same regression as was used in Section 4.4 is used here to test the asymmetric response implication. Table 4.14 presents the test results. In six of the twelve industries sampled the null hypothesis that $\beta^P - \beta^T = 0$ is rejected in favor of $\beta^P - \beta^T > 0$ at the .05 level of significance. These industries are "Motors and Generators," "Electric Lamps," "Transformers," "Glass Containers," "Mens' and Boys' Separate Trousers," and "Metal Cans."

The large improvements in the power of the t-test which resulted from applying the band pass filter occured in "Blast Furnaces and Steel Mills," "Electric Lamps," "Transformers," "Mens' and Boys' Separate Trousers," "Metal Cans," and "Metal Doors, Sash and Trim."

Overall the power of the test is improved by applying the band pass filter. The most important gain from applying this technqiue is that it results in 6 industries strongly rejecting the null hypothesis that $\beta^P - \beta^T = 0$ in favor of the alternative hypothesis that $\beta^P - \beta^T > 0$.

Still, it would be desirable to be able to say whether the results, in general, support the asymmetric response implication. In order to do this, the regression equations employing the band pass filter are estimated as a system of seemingly unrelated regression equations. This not only improves the efficiency of the parameter estimates but it also allows the

TABLE 4.14: Asymmetric Wage Response Test Results: Band Pass Filter Applied to $D\ln P_t$

Industry	Frequency Split		β^P	β^T	T for H_0: $\beta^P-\beta^T = 0$	R^2	Ljung-Box Q at 12 lags
	Permanent	Temporary					
Internal Combustion Engines	$0 < \omega_j < 2\pi/11.25$	$2\pi/3 < \omega_j < \pi$	.41 (.12)	.11 (.23)	1.19 (.12)	.17	3.90 (9.85)
Blast Furnaces and Steel Mills	$0 < \omega_j < 2\pi/11.25$	$2\pi/3 < \omega_j < \pi$	.24 (.09)	.06 (.14)	1.09 (.14)	.24	3.51 (.991)
Primary Aluminum	$0 < \omega_j < 2\pi/15$	$2\pi/3.7 < \omega_j < \pi$	.072 (.07)	.019 (.10)	.43 (.33)	.25	2.38 (.999)
Motors and Generators	$0 < \omega_j < 2\pi/22.5$	$2\pi/3.8 < \omega_j < \pi$	.36 (.11)	-.008 (.16)	1.94 (.03)	.16	1.98 (.999)
Printing Trades Machinery	$0 < \omega_j < 2\pi/7.2$	$2\pi/2.95 < \omega_j < \pi$	.16 (.14)	.08 (.18)	.36 (.36)	.14	3.05 (.995)
Electric Lamps	$0 < \omega_j < 2\pi/8.2$	$2\pi/3.2 < \omega_j < \pi$	.27 (.08)	.03 (.08)	2.11 (.02)	.15	6.34 (.898)
Transformers	$0 < \omega_j < 2\pi/22.5$	$2\pi/4.2 < \omega_j < \pi$	.30 (.097)	.002 (.03)	2.97 (.002)	.09	4.59 (.970)
Glass Containers	$0 < \omega_j < 2\pi/5.1$	$2\pi/2.8 < \omega_j < \pi$	.39 (.08)	-.11 (.14)	3.00 (.002)	.30	4.34 (.976)
Mens' and Boys' Separate Trousers	$0 < \omega_j < 2\pi/6.7$	$2\pi/3.1 < \omega_j < \pi$	.40 (.12)	.093 (.0960	1.98 (.02)	.31	5.28 (.948)
Metal Cans	$0 < \omega_j < 2\pi/6.9$	$2\pi/3 < \omega_j < \pi$	.18 (.08)	-.008 (.07)	1.80 (.04)	.19	6.16 (.909)
Metal Doors, Sash and Trim	$0 < \omega_j < 2\pi/11.3$	$2\pi/3.6 < \omega_j < \pi$	.35 (.12)	.07 (.13)	1.25 (.11)	.22	4.32 (.977)
Sausages and other Prepared Meats	$0 < \omega_j < 2\pi/6$	$2\pi/2.9 < \omega_j < \pi$	-.03 (.09)	-.02 (.10)	-.07 (.50)	.22	4.97 (.959)

testing of the joint null hypothesis that $\beta^P - \beta^T = 0$ for all industries against the alternative hypothesis that $\beta^P - \beta^T \neq 0$.

Since there is serial correlation present a 3-step procedure is employed. First, the autoregressive filter is estimated from the individual industry regression residuals. The filter is applied to $DlnW_t$, $DlnP_t^P$, and $DlnP_t^T$ for all industries. The regressions are reestimated using the filtered data and the covariances of the error terms among the individual industry regressions are estimated. The final step involves reestimating the industry regressions using generalized least squares (see Kmenta, 1971, pp. 517-529).

To test the asymmetric response implication the system is estimated with each industry regression equation taking the form (4.5). The sum of the squared residuals from this unrestricted system are denoted by USSR. The system is then estimated with the constraint that $\beta^P - \beta^T = 0$ for each industry. The sum of the squared residuals from this restricted system are denoted by RSSR. The following F-statistic is then calculated:

$$F_{q,N-k} = \frac{(RSSR - USSR)/q}{USSR/N-k}$$

where q is the number of restrictions (in this case 12) and k is the number of estimated parameters in the unrestricted regression (in this case 36). The F-statistic for this set of restrictions is equal to 2.78 which exceeds $F_{12,1980} = 2.18$ at the .01 level of significance. We may therefore conclude that as a system, the 12 industries support the asymmetric response implication.

4.6 Summary and Conclusions

The purpose of this chapter was to present empirical evidence on risk shifting in the labor market. The implication that the real wage responds more to permanent shocks than to temporary shocks was tested on 12 4-digit SIC code industries.

Industry output price was decomposed into permanent and temporary components and the real wage was regressed on each component. The results presented here tend to support the implication that the real wage responds more to a permanent shock than to a temporary shock.

In Section 4.4, results were presented which show that 7 of the 12 industries support the asymmetric response implication at the .10 level of significance. In Section 4.5, results were presented which show that 6 of the 12 industries support the asymmetric response implication at the .05 level. The industries were then estimated as a system of seemingly unrelated regressions. The joint hypothesis of asymmetric wage response is supported for the group of industries at the .01 level of significance.

FOOTNOTES

[1]Work by Lucas (1980) and Geweke (1985) associate the economic concept of the "long run" with the long frequency components of variables.

[2]This is to eliminate the possibility of spurious regression results which may result when one nonstationary time series is regressed on another nonstationary time series.

[3]The highest frequency which we can identify in any time series is $\pi/2$ or 1/2 full cycle every time period. Higher frequency components of the data will be folded back into the principle domain: $-\pi/2 < \omega_j < \pi/2$.

[4]The data set length was chosen so that $N/2 = 90$ is an integer.

CHAPTER 5

SUMMARY AND CONCLUSION

The purpose of this dissertation was to investigate whether the risk shifting aspect of implicit contracts could be empirically identified. Chapter 2 demonstrated that the co-movements in industry level nominal wages and employment are explained by a model in which risk neutral workers insure risk averse firms. Under the more plausible assumption that firms are risk neutral and workers are risk averse (or, more generally, firms are less risk averse than workers) the model is refuted by the observed behavior of industry level nominal wages.

Chapter 3 demonstrated that risk shifting may be identified by observing the real wage response to permanent and temporary disturbances to the firm's revenue function. If risk neutral firms are insuring risk averse workers then the real wage will respond more to a permanent shock than to a temporary shock.

Chapter 4 developed a test of the asymmetric wage response implications and applied it to 12 4-digit SIC code industries. Measures of permanent and temporary revenue function disturbances were obtained by decomposing the industry output price into its frequency components and associating the long frequency components with the permanent movements in the data and the short frequency components with the temporary movements in the data. Seven out of the 12 industries sampled support the asymmetric response implication at the .10 level of significance and 6 of the 12 support it at the .05 level of significance.

As a group, the 12 industries support the asymmetric response implication at the .01 level of significance.

The primary contribution of this dissertation is the identification and testing of a new implication associated with risk shifting in the labor market, namely, the asymmetric real wage response implication. Chapter 2 tells us that we should focus our attention away from the period by period co-movements in nominal wages and employment for the purpose of identifying risk shifting. Chapter 3 tells us to focus on the dynamic response of the real wage to permanent and temporary shocks. Chapter 4 tells us that there is evidence of risk shifting in the 12 industries sampled.

References

Azariadis, C., "Implicit Contracts and Underemployment Equilibria." Journal of Political Economy, Vol. 83, 1975.

__________ and Stiglitz,J., "Implicit Contracts and Fixed-Price Equilibria," Quarterly Journal of Economics, Supplement 1983.

Akerlof, G. and Miyazaki, H., "The Implicit Contract Theory of Unemployment Meets the Wage Bill Argument," Review of Economic Studies, Vol. 47, 1983.

Baily, M.N., "Wages and Employment under Uncertain Demand," Review of Economic Studies, Vol. 41, 1974.

Barro, R.J., "Long Term Contracting, Sticky Prices and Monetary Policy," Journal of Monetary Economics, July 1977.

Bloomfield, P., Fourier Analyses of Time Series: An Introduction, John Wiley and Sons, Inc., New York, 1976.

Browning, M., Deaton, Angus and Irish, M., "A profitable Approach to Labor Supply and Commodity Demands over the Life-Cycle, " Econometrica, Vol. 53, no. 3, 1985.

Bull, C., "Implicit Contracts in the Absence of Enforcement and Risk Aversion," American Economic Review, Vol. 73, 1983.

Cantor, R., "Long-Term Contracts, Consumption Smoothing and Aggregate Wage Dynamics," unpublished manuscript, Ohio State University, 1984.

Chari, V., "Involuntary Unemployment under Implicit Contracts," Quarterly Journal of Economics, Supplement 1983.

Farmer. R., "A New Theory of Aggregate Supply," American Economic Review, Vol. 74, 1984.

__________, "Implicit Contracts with Asymmetric Information and Bankruptcy: The Effect of Interest Rates on Layoffs," Review of Economic Studies, Vol. 53, 1985.

Fischer, S., "Long-Term Contracts, Rational Expectations, and the Optimal Money Supply Rule," Journal of Political Economy, Vol. 85, No. 1, 1977(a).

__________, "Wage Indexation and Macroeconomic Stability," Carnegie-Rochester Conference Series on Public Policy, Vol. 5, 1977(b).

Geweke, J., "The Superneutrality of Money in the United States: An Interpretation of the Evidence," Econometrica, Vol. 55, No. 1, 1985.

Gordon, Donald F., "A Neoclassical Theory of Keynesian Unemployment," Economic Inquiry, 1974, pp.431-59.

Gray, J., "Wage Indexation: A Macroeconomic Approach," Journal of Monetary Economics, Vol. 2, 1976.

______. "On Indexation and Contract Length," Journal of Political Economy, Vol. 86, No. 1, 1978.

Grossman, H., "Risk-Shifting and Reliability in Labor Markets," Scandinavian Journal of Economics, Vol. 79, 1977.

Grossman, S. and Hart, O., "Implicit Contracts, Moral Hazard and Unemployment," American Economic Review (Papers and Proceedings), Vol. 71, 1981.

Green, J. and Kahn, M., "Wage-Employment Contracts." Quarterly Journal of Economics, 1983, Supplement.

Hogg, R. and Craig, A., Introduction to Mathematical Statistics, Third Edition, Macmillan Publishing Company, Inc., 1970.

Holmstrom B., "Contractual Models of the Labor Market," American Economic Review, Vol. 71, 1981.

__________, "Equilibrium Long - Term Contracts," Quarterly Journal of Economics," Supplement 1983.

Kahn, C. and Scheinkman, J., "Optimal Employment Contracts with Bankruptcy Constraints," Journal of Economic Theory, Vol. 35, 1985.

Kmenta, J., Elements of Econometrics, Macmillan Publishing Company, Inc. 1971.

Ljung, G. and Box, G., "On a Measure of Lack of Fit in Time Series Models," Biometrika, 65, 1978.

Raisian J., "Contracts, Job Experience and Cyclical Labor Market Adjustments," Journal of Labor Economics, Vol. 1.1, 1983.

Rosen, S., "Implicit Contracts: A Survey," Journal of Economic Literature, Vol. 23, No. 3, 1985.

Rothschild, M. and Stiglitz, J., "Equilibrium in Competitive Insurance Markets: An Essay on the Economics of Imperfect Information," Quarterly Journal of Economics, Vol. 90, 1976.

Schultze, C. "Microeconomic Efficiency and Nominal Wage Stickiness," American Economic Review, Vol. 75, No. 1, 1985.

Waldo, D.G., "Sticky Nominal Wages and the Optimal Employment Rule," Journal of Monetary Economics, Vol. 7, 1981.

APPENDIX 1

CONSTRUCTION OF THE PROBABILITY DENSITY FUNCTION $g(P_1,\overline{P})$

We are given that the M industry output prices are jointly distributed stationary random variables with the probability density function $h(P_1,P_2,\ldots P_M)$. The probability density function $h(P_1,P_2,\ldots,P_M)$ has the usual property:

$$\int_{P_1}\int_{P_2}\cdots\int_{P_M} h(P_1,P_2,\ldots,P_M)dP_M dP_{M-1}\ldots dP_1 = 1. \qquad \text{(A1.1)}$$

The price level is defined as:

$$\overline{P} = \sum_{i=1}^{M} \alpha_i P_i$$

where $\alpha_i = \dfrac{q_i}{\sum_{j=1}^{M} q_i}$, $i = 1,\ldots,M$.

We wish to construct a probability density function over an arbitrary P_i and $\overline{P}$. We choose $i = 1$ and denote this probability density function by $g(P_1,\overline{P})$.

<u>Step 1</u>: Define the following variable transformations:

$$P_1' = P_1$$

$$P_2' = P_2$$

$$\vdots$$

$$P_{M-1}' = P_{M-1}$$

$$\overline{P} = \sum_{i=1}^{M} \alpha_i P_i$$

Step 2: Solve these M equations in terms of the original variables:

$$P_1 = P_1'$$

$$P_2 = P_2'$$

$$\vdots$$

$$P_{M-1} = P_{M-1}'$$

$$P_M = \frac{\overline{P} - \sum_{j=1}^{M-1} \alpha_j P_j}{\alpha_M}$$

Step 3: Construct the Jacobian of the transformation matrix:

$$\begin{vmatrix} \frac{\partial P_1}{\partial P_1'} & \frac{\partial P_1}{\partial P_2'} & \cdot\ \cdot\ \cdot & \frac{\partial P_1}{\partial \overline{P}} \\ \frac{\partial P_2}{\partial P_1'} & & & \\ \vdots & & & \\ \frac{\partial P_M}{\partial P_1'} & \frac{\partial P_M}{\partial P_2'} & \cdot\ \cdot\ \cdot & \frac{\partial P_M}{\partial \overline{P}} \end{vmatrix} = \begin{vmatrix} 1 & 0 & \cdot\ \cdot\ \cdot\ \cdot & \\ 0 & 1 & \cdot & \\ \vdots & \vdots & \ddots & \\ \frac{-\alpha_2}{\alpha_M} & \frac{-\alpha_2}{\alpha_M} & \cdot\ \cdot\ \cdot\ \cdot & \frac{1}{\alpha_M} \end{vmatrix} = \frac{1}{\alpha_M}$$

Step 4: Rewrite integral A1.1 over the transformed variables to get (see Hogg and Craig (1970), pp. 125-128):

$$\int_{P_1}\int_{P_2}\cdots\int_{P_M} h(P_1,\ldots,P_M)\,dP_1dP_2\ldots dP_M$$

$$= \int_{P_1}\int_{P_2}\cdots\int_{\overline{P}} h(P_1,P_2\ldots\overline{P})\,\frac{1}{\alpha_M}\,dP_1dP_2\ldots dP_M = 1$$

Step 5: Integrate out over $P_2\ldots P_{M-1}$ to get the probability density function $g(P_1,\overline{P})$:

$$g(P_1,\overline{P}) = \int_{P_1}\int_{P_2}\cdots\int_{P_{M-1}} h(P_1,P_2,\ldots,P_M)\,\frac{1}{\alpha_M}\,dP_2dP_3\ldots dP_{M-1}$$

APPENDIX 2

THE LAGRANGIAN AND COMPARATIVE STATICS RESULTS FOR THE MODEL PRESENTED IN CHAPTER 2

I. The Lagrangian for (2.6) and (2.7):

$$J(W,L,\lambda)= \int_{P_1}\int_{\overline{P}} V\left(\frac{P_1}{\overline{P}} f(L)- \frac{WL}{\overline{P}}\right)g(P_1,\overline{P})d\overline{P}dP_1$$

$$+\lambda\left\{ \int_{P_1}\int_{\overline{P}} U\left(\frac{WL}{\overline{P}}, \tau-L\right)g(P_1,\overline{P})dP_1d\overline{P} - \overline{U} \right\} \qquad (A2.1)$$

II. Under Assumption 1, first order conditions (2.8) and (2.9) become the following

$$\frac{P_1}{\overline{P}} f' - \frac{W}{\overline{P}} + \lambda\left(U_1 \frac{W}{\overline{P}} - U_2\right) = 0 \qquad (A2.2)$$

$$U_1 = \frac{1}{\lambda} \qquad (A2.3)$$

Totally differentiating (2.2) and (2.3) we get

$$\begin{bmatrix} Q_{11} & Q_{12} \\ Q_{21} & Q_{22} \end{bmatrix} \begin{bmatrix} \frac{dL}{L} \\ \frac{dW}{W} \end{bmatrix} = \begin{bmatrix} \left[\frac{P_1}{\overline{P}}f' - \lambda \frac{WL}{\overline{P}} \left(U_{11} \frac{W}{\overline{P}} - U_{21}\right)\right] \frac{d\overline{P}}{\overline{p}} - \frac{P_1}{\overline{P}} f' \frac{dP_1}{P_1} \\ U_{11} \frac{WL}{\overline{P}} \frac{d\overline{P}}{\overline{P}} \end{bmatrix}$$

where

$$Q_{11} = \frac{LP_1}{\overline{P}} f'' + \lambda\frac{LW}{\overline{P}} \left(U_{11} \frac{W}{\overline{P}} - U_{12}\right) + L\lambda\left(U_{22} - U_{21} \frac{W}{\overline{P}}\right)$$

$$Q_{12} = \lambda \frac{LW}{\bar{P}} (U_{11} \frac{W}{\bar{P}} - U_{12})$$

$$Q_{21} = (U_{11} \frac{W}{\bar{P}} - U_{12})L$$

$$Q_{22} = U11 \frac{WL}{\bar{P}}$$

Denoting the Jacobian by Q we have

$$Q = Q_{11}Q_{22} - Q_{12}Q_{21} = (U_{11}U_{22} - U_{12}^2)\lambda L + \frac{LP_1}{\bar{P}} f'' U_{11} > 0$$

by the concavity assumptions on the utility and production functions.

Solving the system for $\frac{dW}{W}$ and $\frac{dL}{L}$ yields the following:

$$\frac{dW}{W} = \frac{d\bar{P}}{\bar{P}} - \gamma_1 (\frac{dP_1}{P} - \frac{d\bar{P}}{\bar{P}}) \quad \text{(A2.4)}$$

$$\frac{dL}{L} = \gamma_2 (\frac{dP_1}{P} - \frac{d\bar{P}}{\bar{P}}) \quad \text{(A2.5)}$$

where γ_1 and γ_2 are defined as follows:

$$\gamma_1 = - \frac{(U_{11}\frac{W}{P} - U_{12}) f' \frac{LP_1}{\bar{P}}}{Q}$$ > 0 by the normality of consumption and leisure assumption.

$$\gamma_2 = \frac{\frac{WL}{\bar{P}} U_{11} f' \frac{P_1}{\bar{P}}}{Q}$$ > 0 by the concavity assumption on the utility and production functions.

III. Under Assumption 2, first order conditions (2.8) and (2.9) become the following:

$$V'\left(\frac{P_1}{\bar{P}} f' - \frac{W}{\bar{P}}\right) + \lambda\left(\frac{W}{\bar{P}} - 1\right) = 0 \qquad \text{(A2.6)}$$

$$V' = \lambda \qquad \text{(A2.7)}$$

Totally differentiating (A4) and (A5) we get

$$\begin{bmatrix} R_{11} & R_{12} \\ R_{21} & R_{22} \end{bmatrix} \begin{bmatrix} \frac{dL}{L} \\ \frac{dW}{W} \end{bmatrix} = \begin{bmatrix} - V'\frac{P_1}{\bar{P}}f'\left(\frac{dP_1}{P_1} - \frac{d\bar{P}}{\bar{P}}\right) + V''\Delta\pi\frac{d\bar{P}}{\bar{P}} - V''\Delta\frac{P_1}{\bar{P}}f\frac{dP_1}{P_1} \\ \pi\frac{d\bar{P}}{\bar{P}} - \frac{P_1}{\bar{P}}f\frac{dP_1}{P_1} \end{bmatrix}$$

where

$$R_{11} = \frac{LP1}{\bar{P}}f'' + L\Delta^2V'' \qquad R_{21} = \Delta L \qquad \Delta = \frac{P_1}{\bar{P}}f' - \frac{W}{\bar{P}}$$

$$R_{12} = - \Delta V''\frac{WL}{\bar{P}} \qquad R_{22} = - \frac{WL}{\bar{P}} \qquad \pi = \frac{P_1}{\bar{P}}f - \frac{WL}{\bar{P}}$$

Denoting the Jacobian by R we have

$$R = R_{11}R_{22} - R_{12}R_{21} = - \frac{WL^2P_1}{\bar{P}^2}f'' > 0$$ by the concavity assumption on the production function.

Solving the system for $\frac{dW}{W}$ and $\frac{dL}{L}$ yields the following:

$$\frac{dW}{W} = \frac{d\overline{P}}{\overline{P}} - \gamma_3\left(\frac{dP_1}{P} - \frac{d\overline{P}}{\overline{P}}\right) \tag{A2.8}$$

$$\frac{dL}{L} = \gamma_4\left(\frac{dP_1}{P} - \frac{d\overline{P}}{\overline{P}}\right) \tag{A2.9}$$

where γ_3 and γ_4 are defined as follows:

$$\gamma_3 = \frac{P1}{\overline{P}}f - \frac{P\Delta V'f'}{WLf''} > 0 \quad \text{if } \Delta > 0.$$

$$\gamma_4 = -\frac{V'f'}{Lf''} > 0 \text{ by the concavity assumption on the production function.}$$

APPENDIX 3

THE RIGID WAGE RESULT

The models presented in Azariadis (1975) and Baily (1974) have two assumptions that differ from the model presented in Chapter 2. First, they assumed that utility is separable in consumption and leisure. Second, instead of a continuous employment variable they assumed that the worker's labor supply is discrete, that is, the worker is either employed or unemployed.

Consider the implications of the separable utility function assumption. Assume that utility takes the following form:

$$U(C, \tau - L) = \phi(C) + \Psi(\tau - L) \tag{A3.1}$$

where $\phi', \Psi' > 0$ and $\phi'', \Psi'' < 0$.

Replacing (2.3) in the text with (A3.1) and carrying out the maximization problem, the first order condition for the wage implies the following:

$$\phi'\left(\frac{W(P_1,\overline{P})}{\overline{P}} L(P_1,\overline{P}) \right) = \phi'\left(\frac{W(P_1{}^*,\overline{P}^*)}{\overline{P}^*} L(P_1{}^*,\overline{P}^*)\right) \tag{A3.2}$$

for any arbitrary pair of states $(P_1,\overline{P})$ and $(P_1{}^*,\overline{P}^*)$.

Condition (A3.2) says that the optimal contract will call for constant income across states of nature. Since there is no effect of a change in leisure on the marginal utility of consumption, changes in employment must be offset by changes in the real wage to keep income constant. The signs of the differentials of W and L remain the same as those presented in the text; however, an additional restriction is obtained:

$$\frac{d\left(\frac{W(P_1,\overline{P})}{\overline{P}}\right)}{d\overline{P}} = -\frac{dL(P,\overline{P})}{d\overline{P}} .$$

Under the assumption of a discrete employment choice variable the first order condition for the wage implies the following:

$$U_1\left(\frac{W(P_1,\overline{P})}{\overline{P}}\overline{L},\ \tau - \overline{L}\right) = U_1\left(\frac{W(P_1{}^*,\overline{P}^*)}{\overline{P}^*}\overline{L},\ \tau - \overline{L}\right) \qquad \text{(A3.3)}$$

for any arbitrary states of nature $(P_1,\overline{P})$ and $(P_1{}^*,\overline{P}^*)$, where $\overline{L}$ is the fixed quantity of labor when the worker is employed. Condition (A3.3) implies that the real wage is constant across all states of nature. The rigid wage result depends upon the assumption of a discrete employment variable. Under the more general assumption of a continuous employment variable the real wage is not rigid, and under the assumption of separable utility, income is constant.

APPENDIX 4

THE LAGRANGIAN AND COMPARATIVE STATICS RESULTS FOR THE MODEL PRESENTED IN CHAPTER 3

The firm's objective is to choose $\{W_{ij}\}$, $\{\hat{W}_{ijk}\}$ to maximize (3.1) subject to constraints (3.2), (3.3) and (3.5). The Lagrangian function for this problem may be written as follows:

$$\max_{\{W_{ij},\hat{W}_{ijk}\}} J(W_{ij},\hat{W}_{ijk},\lambda,\phi_{ij},\gamma_{ijk},\ i = 1,\dots,M,\ j = 1,\dots,N,\ k = 1,\dots,N)$$

$$= \sum_i \sum_j \rho_i q_j (Y_{ij} - W_{ij}) + \beta \sum_i \sum_j \sum_k \rho_i q_j q_k (\hat{Y}_{ik} - \hat{W}_{ijk})$$

$$+ \lambda[\sum_i \sum_j \rho_i q_j U(W_{ij}) + \beta \sum_i \sum_j \sum_k \rho_i q_j q_k U(\hat{W}_{ijk}) - \bar{U}]$$

$$+ \sum_i \sum_j \phi_{ij}[(Y_{ij} - W_{ij}) + \beta \sum_k q_k(\hat{Y}_{ik} - \hat{W}_{ijk})]$$

$$+ \sum_i \sum_j \sum_k \gamma_{ijk}[\beta(\hat{Y}_{ik} - \hat{W}_{ijk}) + \max(Y_{ij} - W_{ij},0)].$$

The first order conditions are as follows:

$$\frac{\partial J}{\partial W_{ij}} = \lambda U'(W_{ij}) - \frac{\phi_{ij} + \sum_k \gamma_{ijk}}{\rho_i q_j} - 1 = 0$$

for i, j such that $\max(Y_i - W_{ij},0) = Y_{ij} - W_{ij}$.

$$\frac{\partial J}{\partial W_{ij}} = \lambda U'(W_{ij}) - \frac{\phi_{ij}}{\rho_i q_j} - 1 = 0$$

for i, j, such that $\max(Y_{ij} - W_{ij},0) = 0$.

$$\frac{\partial J}{\partial \hat{W}_{ijk}} = \lambda U'(\hat{W}_{ijk}) - \frac{q_k\phi_{ij} + \gamma_{ijk}}{\rho_i q_j q_k} - 1 = 0$$

for all i, j, k.

$$\frac{\partial J}{\partial \lambda} = \sum_i \sum_j \rho_i q_j U(W_{ij}) + \beta \sum_i \sum_j \sum_k \rho_i q_j q_k U(\hat{W}_{ijk}) - \bar{U} \geq 0$$

with strict equality if $\lambda > 0$.

$$\frac{\partial J}{\partial \phi_{ij}} = Y_{ij} - W_{ij} + \beta \sum_k q_k(\hat{Y}_{ik} - \hat{W}_{ijk}) \geq 0$$

for all i, j, with strict equality if $\phi_{ij} > 0$.

$$\frac{\partial J}{\partial \gamma_{ijk}} = \beta(\hat{Y}_{ik} - \hat{W}_{ijk}) + \max(Y_{ij} - W_{ij}, 0) \geq 0$$

for all i, j, k, with strict equality if $\gamma_{ijk} > 0$.

APPENDIX 5

PERIODOGRAM PLOTS

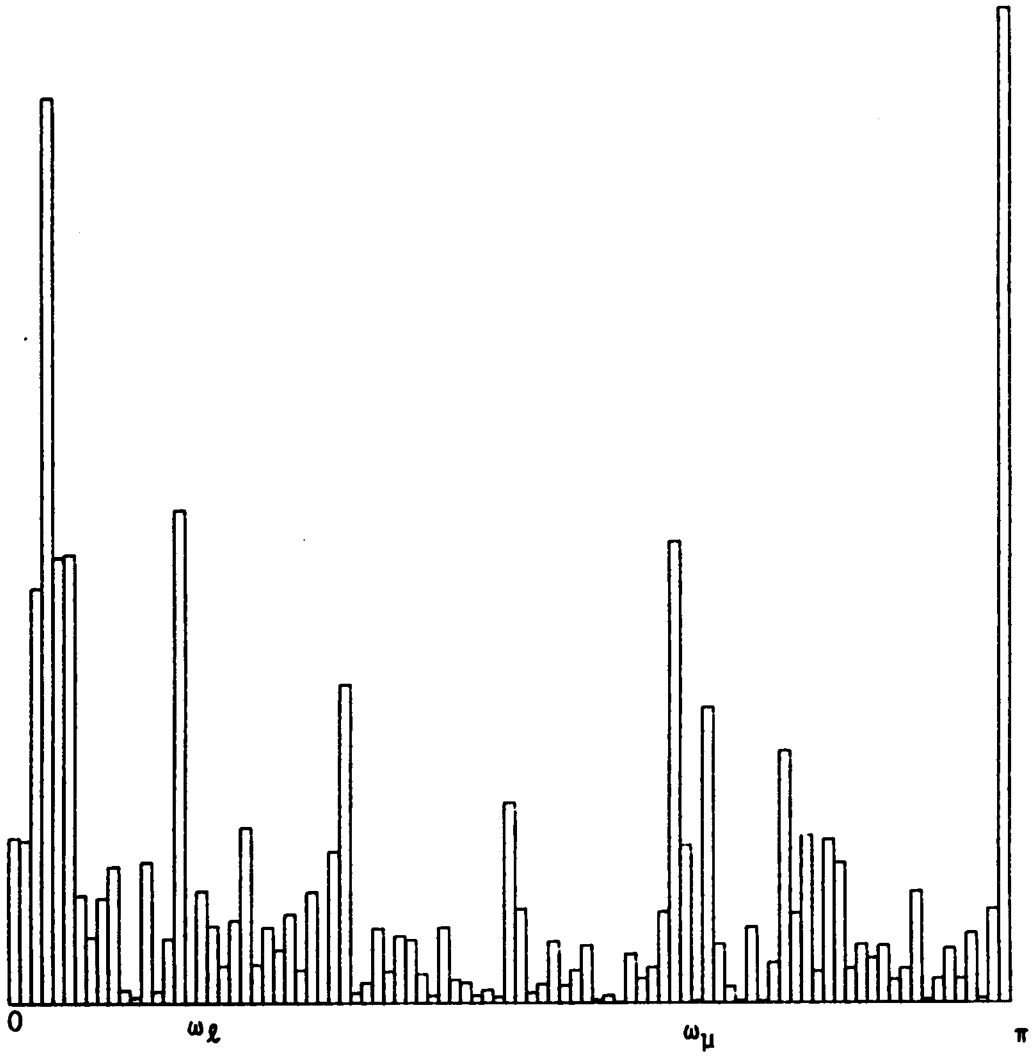

Figure A5.1: Periodogram for $DlnP_t$, Internal Combustion Engines.

ω_ℓ = $2\pi/11.25$
ω_μ = $2\pi/3$

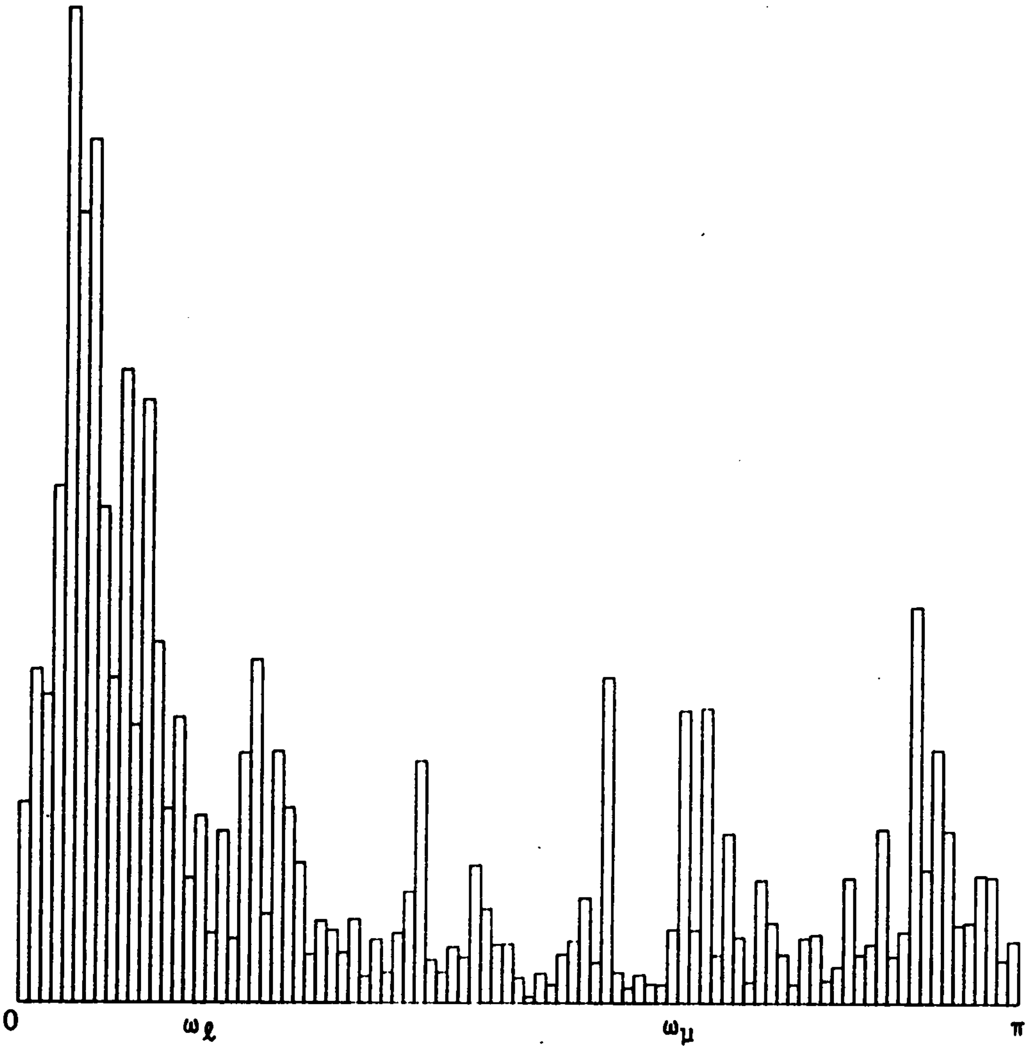

Figure A5.2: Periodogram for $DlnP_t$, Blast Furnaces and Steel Mills.

$\omega_\ell = 2\pi/11.25$
$\omega_\mu = 2\pi/3$

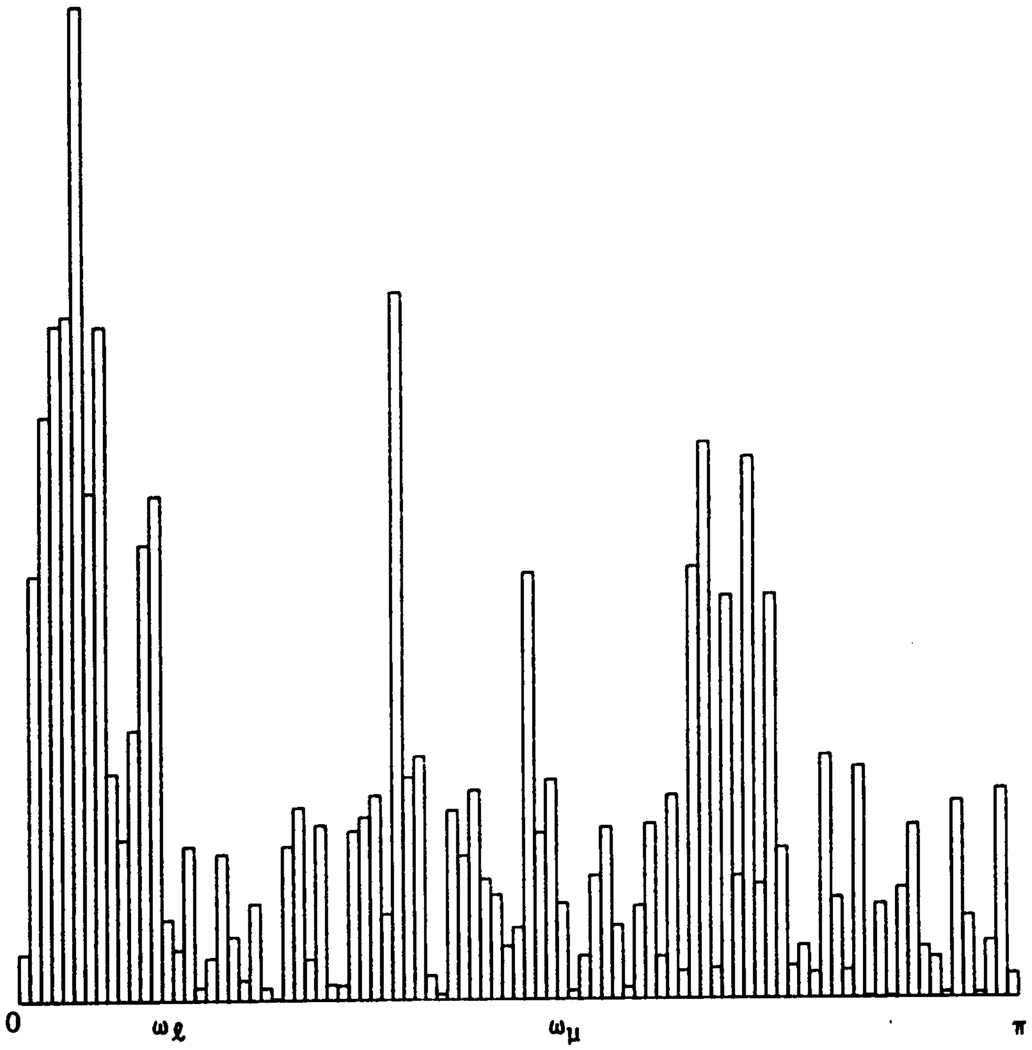

Figure A5.3: Periodogram for $DlnP_t$, Primary Aluminum.

$\omega_\ell = 2\pi/15$
$\omega_\mu = 2\pi/3.7$

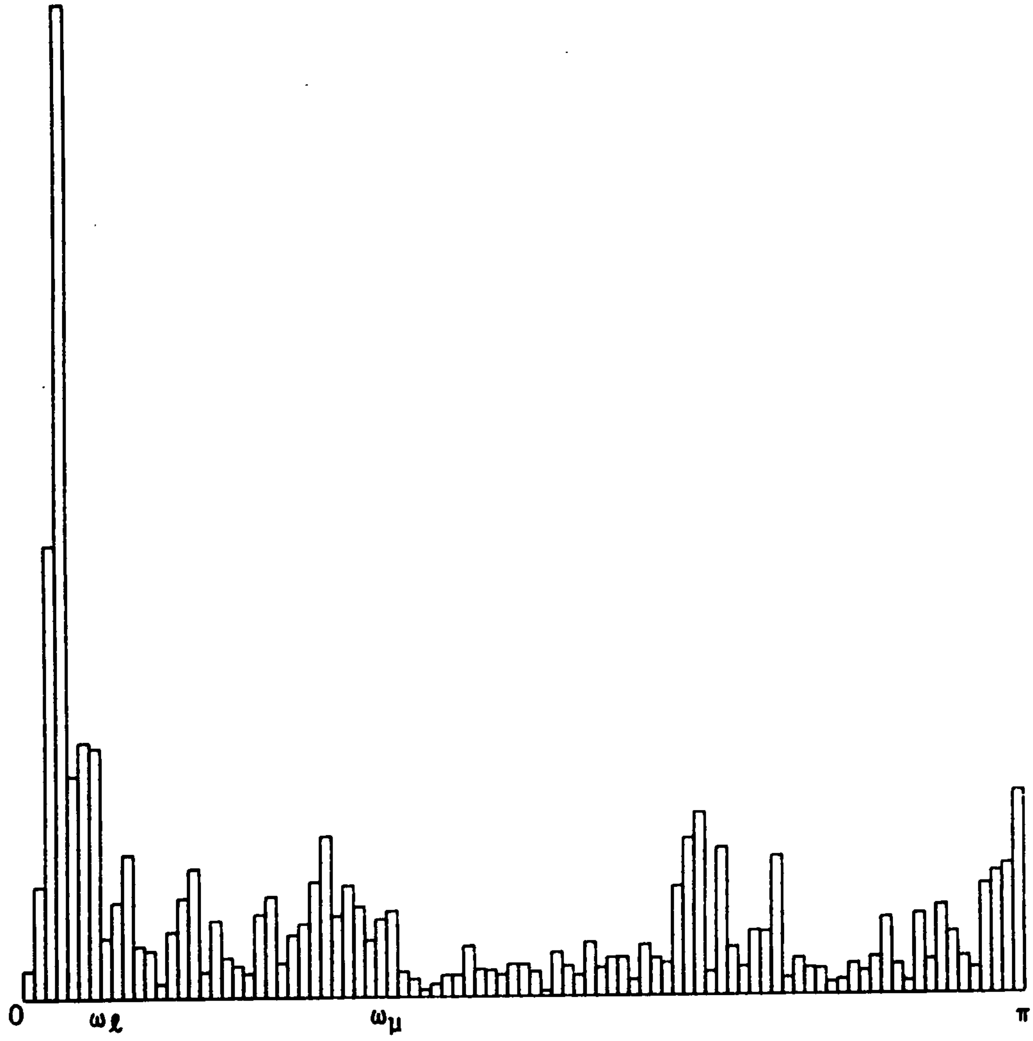

Figure A5.4: Periodogram for $DlnP_t$, Motors and Generators.

$\omega_\ell = 2\pi/22.5$
$\omega_\mu = 2\pi/5.4$

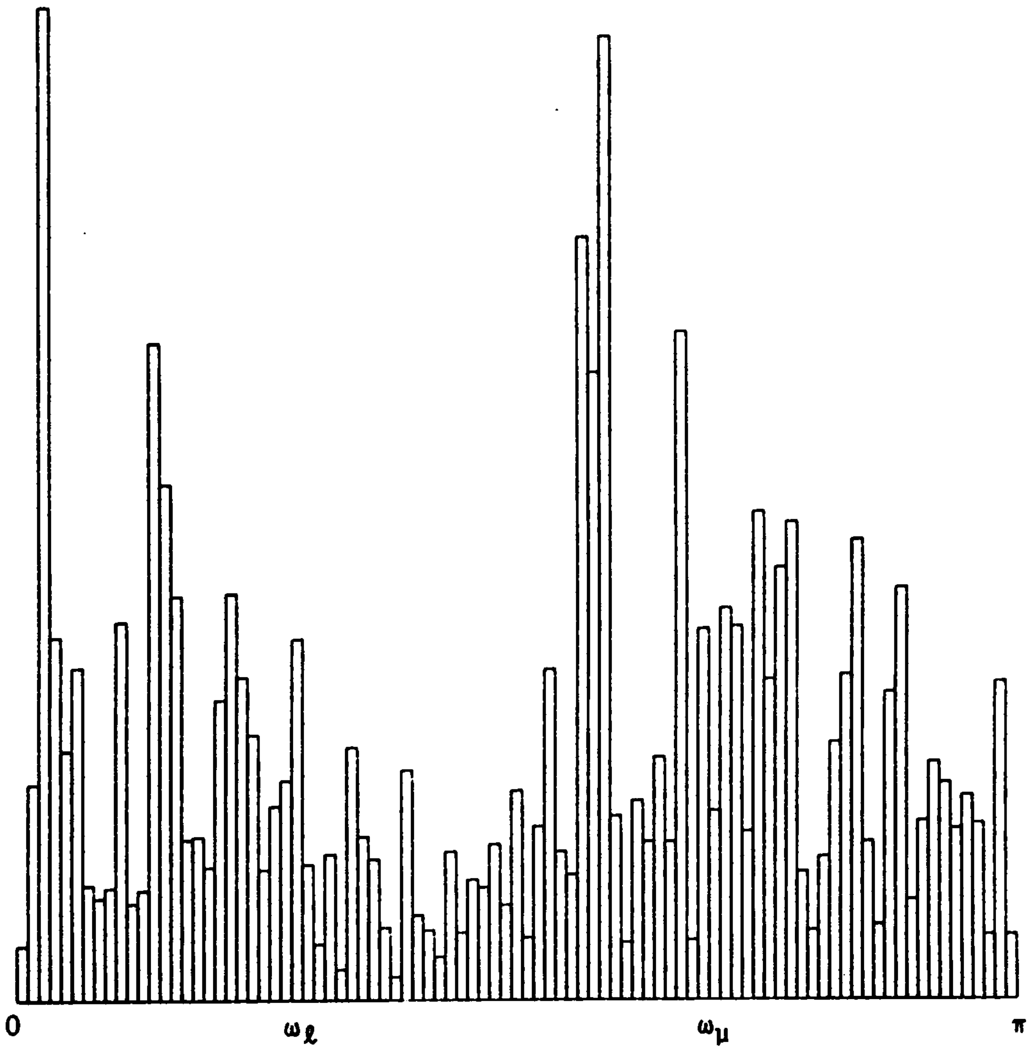

Figure A5.5: Periodogram for $DlnP_t$, Printing Trades Machinery.

$\omega_\ell = 2\pi/7.2$
$\omega_\mu = 2\pi/2.95$

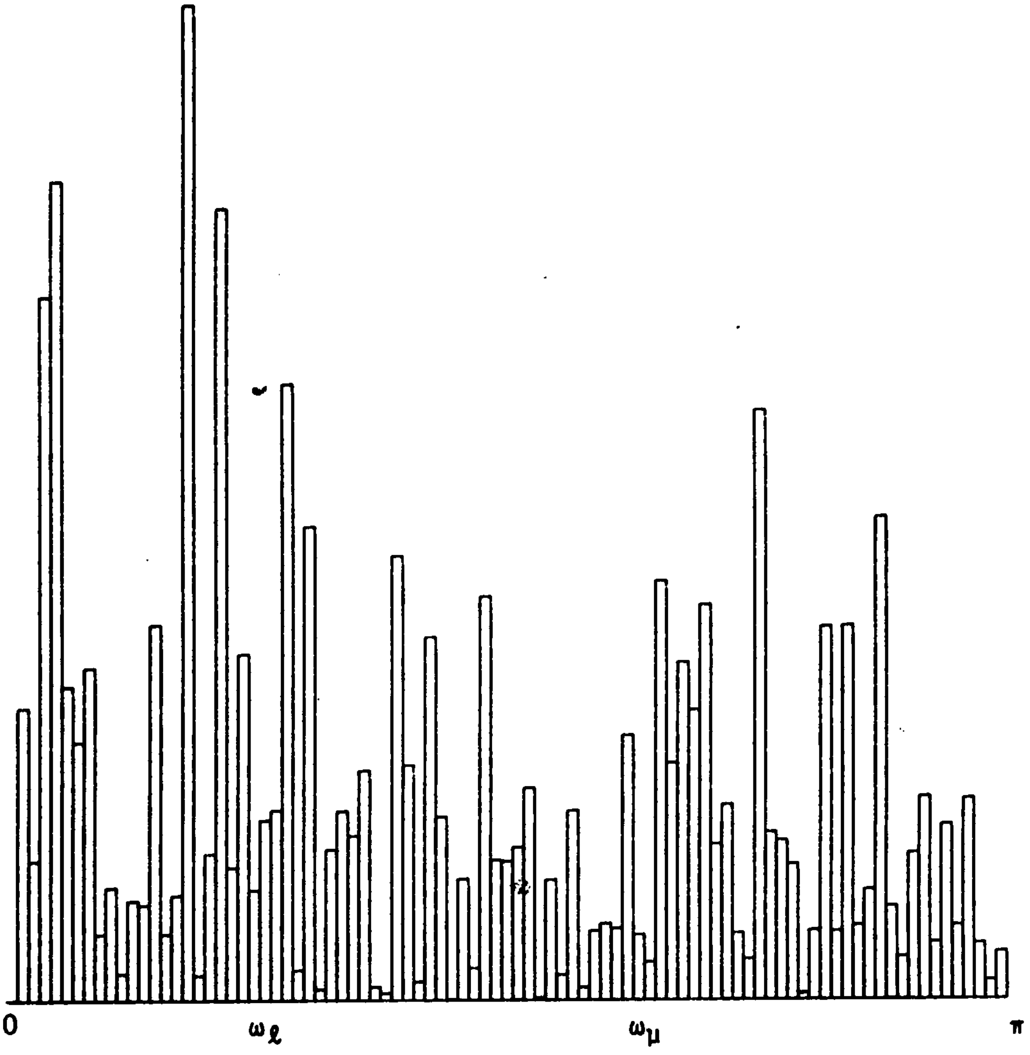

Figure A5.6: Periodogram for $DlnP_t$, Electric Lamps.

$\omega_\ell = 2\pi/8.2$
$\omega_\mu = 2\pi/3.2$

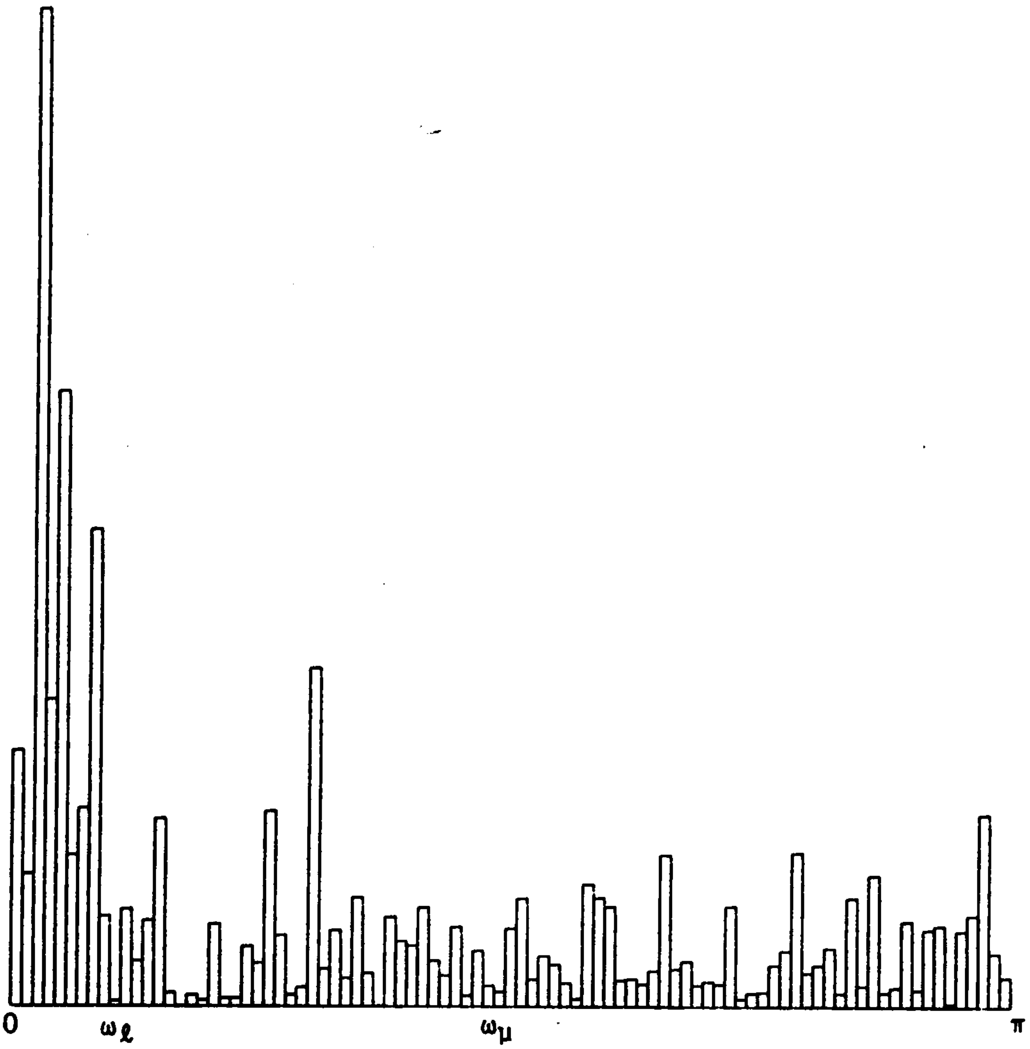

Figure A5.7: Periodogram for $DlnP_t$, Transformers.

$\omega_\ell = 2\pi/22.5$
$\omega_\mu = 2\pi/4.2$

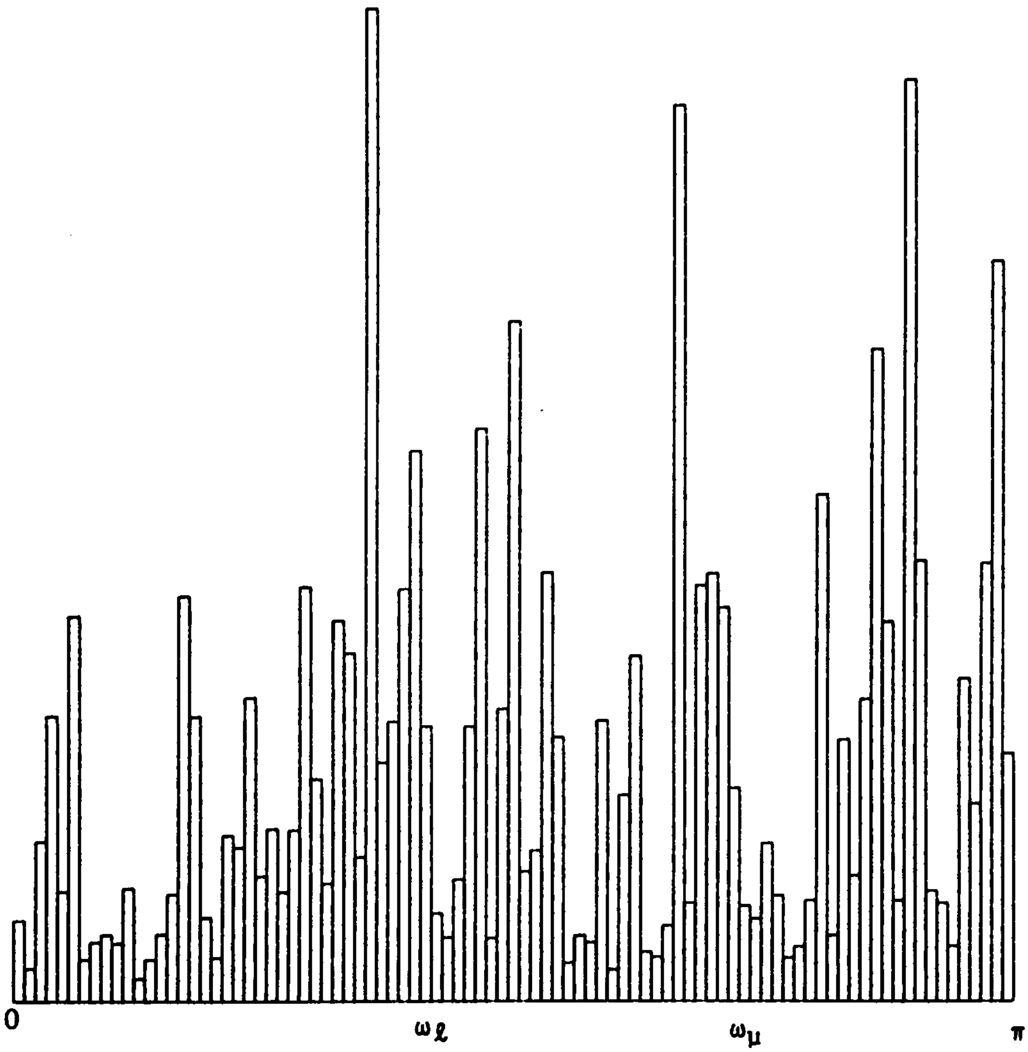

Figure A5.8: Periodogram for $DlnP_t$, Glass Containers

$\omega_\ell = 2\pi/5.1$
$\omega_\mu = 2\pi/2.8$

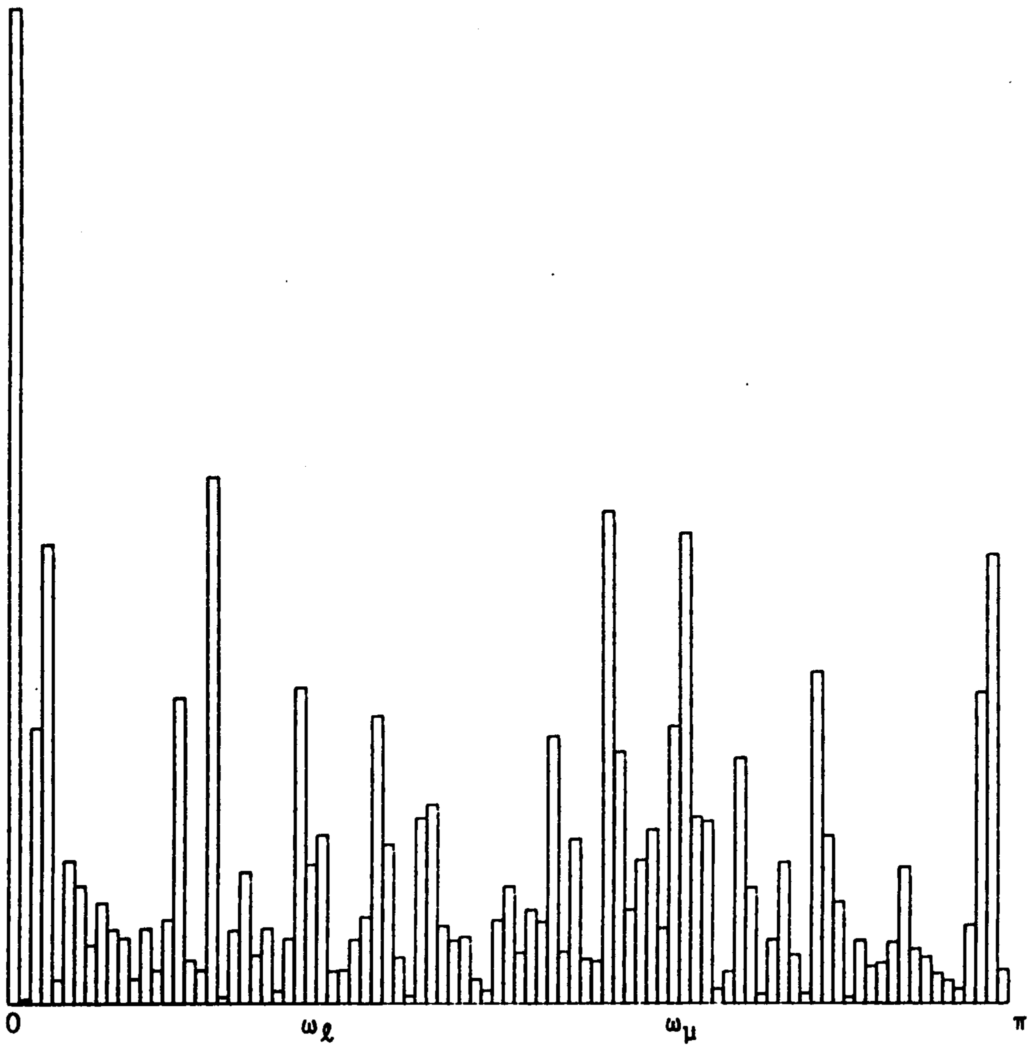

Figure A5.9: Periodogram for $DlnP_t$, Mens' and Boys' Separate Trousers.

$\omega_\ell = 2\pi/6.7$
$\omega_\mu = 2\pi/3.1$

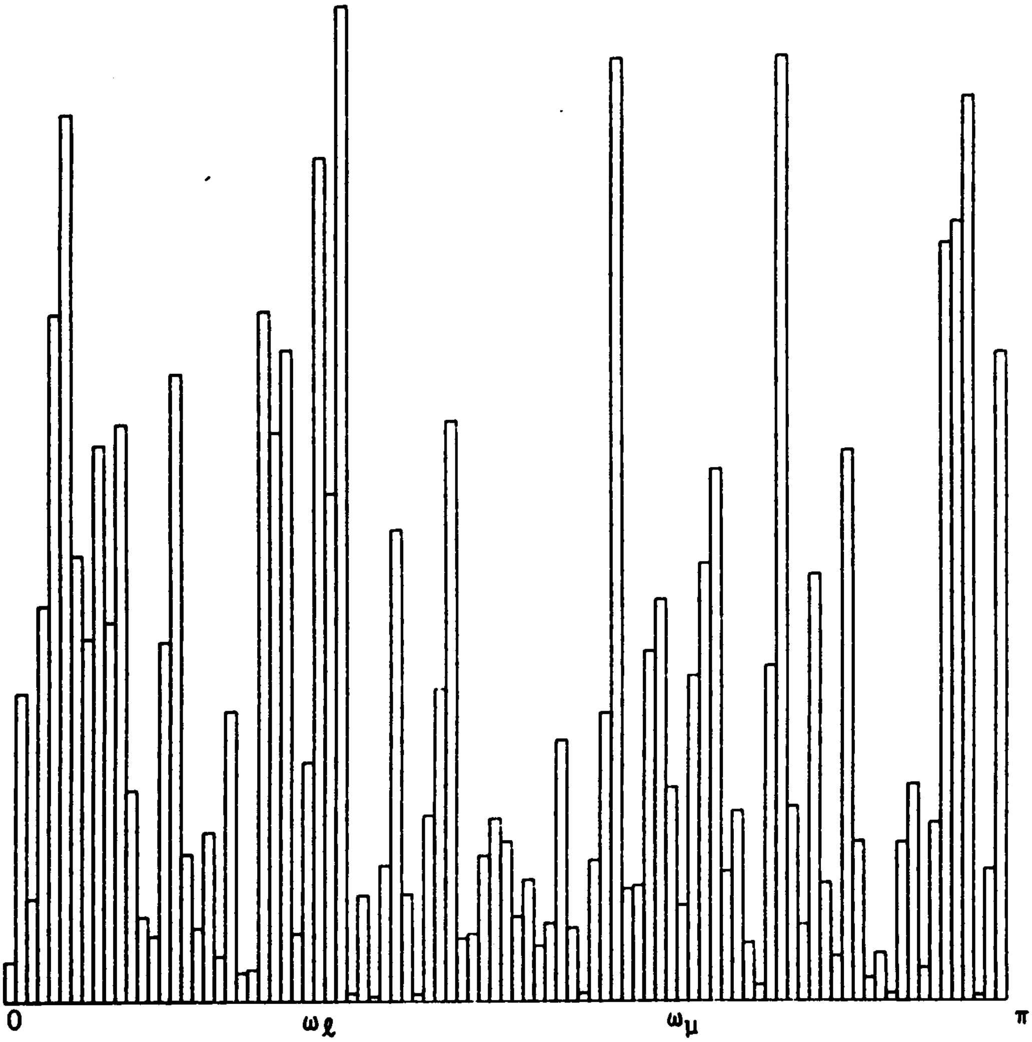

Figure A5.10: Periodogram for $DlnP_t$, Metal Cans.

ω_ℓ = $2\pi/6.9$
ω_μ = $2\pi/3$

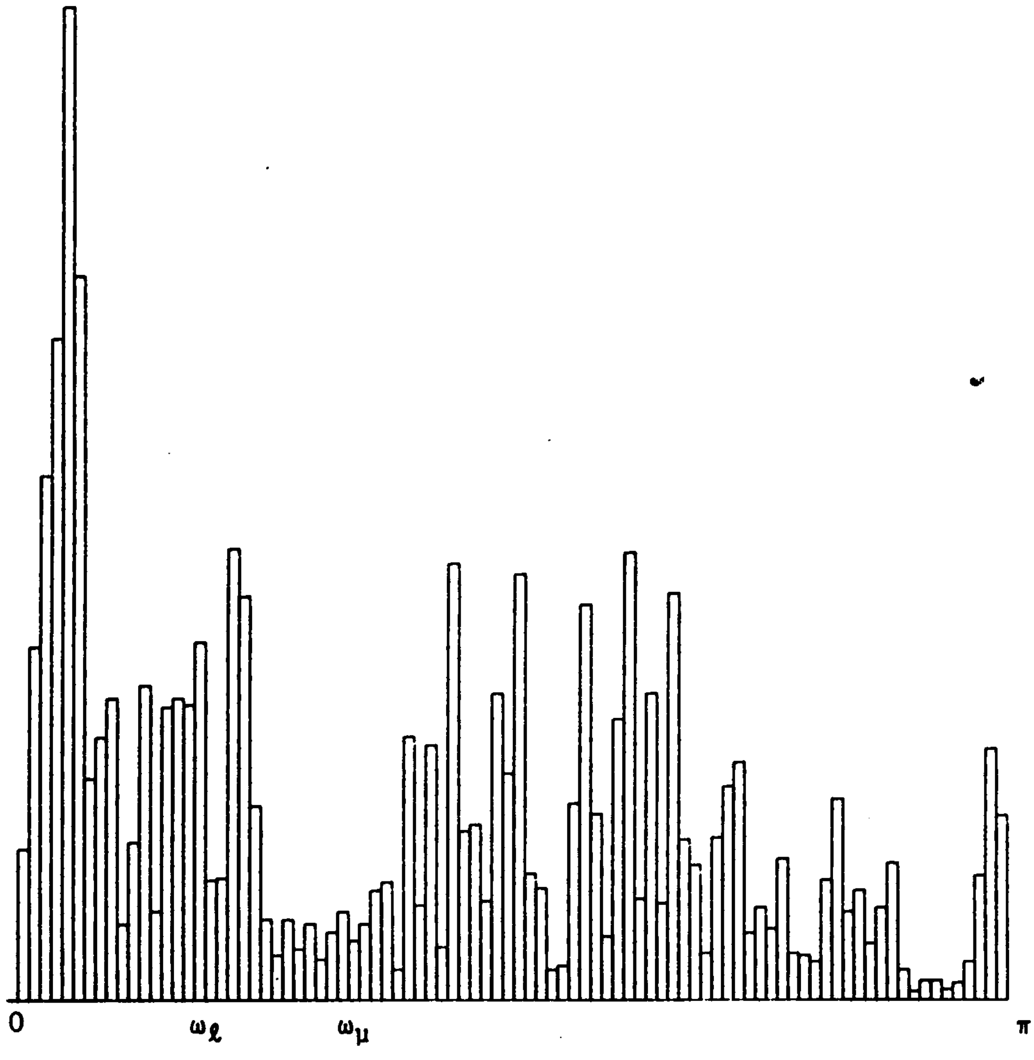

Figure A5.11: Periodogram for $DlnP_t$, Metal Doors, Sash and Trim

$\omega_\ell = 2\pi/11.3$
$\omega_\mu = 2\pi/6$

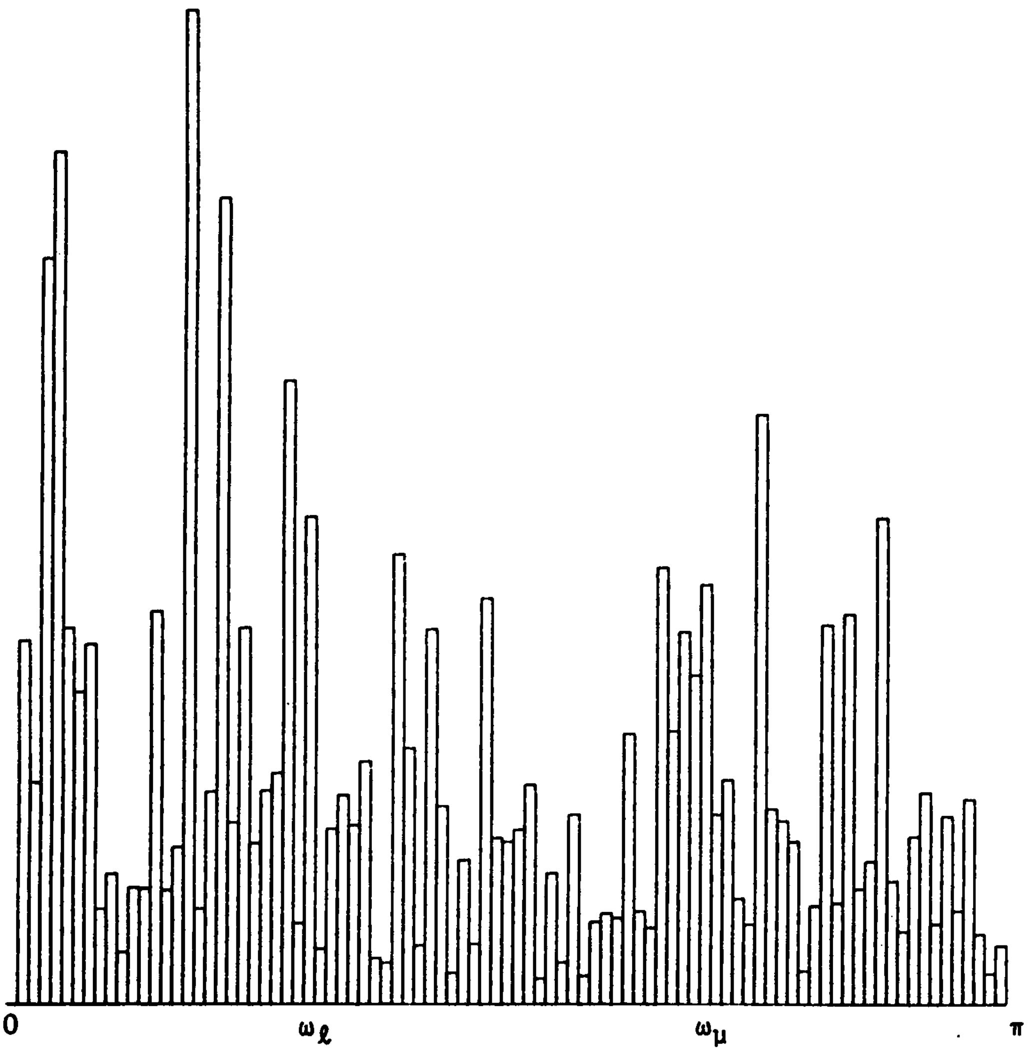

Figure A5.12: Periodogram for $DlnP_t$, Sausages and Other Prepared Meats.

$\omega_\ell = 2\pi/6$
$\omega_\mu = 2\pi/2.9$

The vita has been removed from the scanned document