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UNEMPLOYMENT WITH OBSERVABLE AGGREGATE SHOCKS

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ABSTRACT

Consider an economy subject to two kinds of shocks: (a) an observable shock to the relative demand for final goods which causes dispersion in relative prices, and (b) shocks, unobservable by workers, to the technology for transforming intermediate goods into final goods. A worker in a particular intermediate goods industry knows that the unobserved price of his output is determined by (1) the technological shock that determines which final goods industry uses his output intensively and (2) the price of the final good that uses his output intensively. When there is very little relative price dispersion among final goods, then it doesn't matter which final goods industry uses the worker's output. Thus the technological shock is of very little importance in creating uncertainty about the worker's marginal product when there is little dispersion of relative prices. Hence an increase in the dispersion of relative prices amplifies the effect of technological uncertainty on a worker's marginal value product.

We consider a model of optimal labor contracts in a situation where the workers have less information than the firm about their marginal value product. A relative price shock of the type described above increases the uncertainty which workers have about their marginal value product. We show that with an optimal asymmetric information employment contract the industries which are adversely affected by the relative price shock will contract more than they would under complete information (i.e., where workers could observe their marginal value product). On the other hand the industry which is favorably affected by the relative price shock will not expand by more than would be the case under complete information. Hence an observed relative demand shock, which would leave aggregate employment unchanged under complete information, will cause aggregate employment to fall under asymmetric information about the technological shock.

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1. Introduction

Recent theories of the business cycle have emphasized the misallocations associated with unobserved aggregate shocks.[1/] Agents are assumed to have insufficient information to distinguish a change in their relative position from a change in their absolute position. Here we develop a model where an aggregate shock (e.g., one which impacts on the price level, or aggregate unemployment) is observed by everyone. However the aggregate shock is such that it causes an increase in the uncertainty that workers have about their marginal value product. We show that this leads to a fall in employment below what would occur if workers had complete information.

Azariadis (1982) and Grossman and Hart (1981) have analyzed the optimal labor contract between a firm and its workers in a context where the firm has better information about the real profitability of employment than the workers. If the owners or manager of the firm are risk-averse optimal risk sharing implies that the firm should cut its wage bill when it suffers from low profitability. When the firm's profitability, $\tilde{s}$, is unobservable to the workers, however, there is no way that the wage bill can be directly tied to $\tilde{s}$. Instead, it is optimal for the firm and the worker to agree *ex-ante* to use employment as a device to induce the firm to cut wages only when $\tilde{s}$ is low. In particular the firm and worker agree on a labor contract $W(L;n)$ which ties wages W to employment L, and public information n. Let n_1 denote a public shock which creates uncertainty about a particular firm's marginal product of labor. Let n_2 be the situation where the economy suffers no shock and workers have complete information about their marginal product. In situation n_2, the optimal labor contract will involve setting the marginal wage $W'(L;n_2)$ equal to labor's marginal disutility of effort, say R; while in situation 1 it is optimal to set the marginal wage $W'(L,n_1) > R$ in order to benefit from risk sharing. This can be shown to imply that total employment will be lower in situation 1 than in the complete information Walrasian equilibrium. Consequently shocks which move the economy from n_2 to n_1 but keep total employment in the Walrasian equilibrium constant will lower total employment when there is asymmetric information.

Section 2 reviews the model of an optimal asymmetric information contract when the economy has only one type of firm. It is shown that results derived when an individual firm's employment is the only public information can be extended to situations where any other information not under the firm's control is made public, as long as that information does not perfectly reveal the firm's marginal product of labor.

Section 3 presents an introductory model of the above situation where the economywide shock impacts on the physical productivity of labor. Workers know only the cross sectional distribution of productivities across firms which is induced by the shock. For example workers may know that an oil price shock lowers labor productivity by 75% in half the firms and raises it by 75% in the other half of firms. However a given worker does not know which half his firm is in. We show that the relatively lucky firms do not increase employment by more than they would if their workers had perfect information, while the unlucky firms decrease their employment by more than they would if the workers had perfect information. Thus total employment falls by more than in a Walrasian equilibrium, as a consequence of an increase in the cross sectional dispersion of productivities. Our basic principle is that the only thing that workers can observe is the cross sectional distribution of marginal products. They use this to make an inference about their own marginal product, assuming that their own value is a random drawing from that distribution. Hence an increase in the dispersion of productivities across firms makes workers more uncertain about their own productivity. We are trying to model the idea that workers know how the total demand for labor varies with the observed shock, but not how their own firm's demand for labor is affected by the shock.

Section 4 is the heart of the paper. An economy is considered where there are 3 final consumption goods of which 2 are produced out of intermediate goods, and the third is not produced using current resources (e.g. real balances or the real value of the capital stock). The 2 final produced goods X and Y are made from two intermediate goods K_1 and K_2. The economy is subjected to two types of shocks only one of which is observable by workers. First, the distribution of endowed wealth changes, which changes the demand for the final goods X and Y. This results in an observable change in the prices of the final goods. Second, there are shocks θ, to the technology of transforming intermediate goods into final goods. These shocks are not observed by workers, and change the intensity with which a particular final goods industry uses each intermediate good. Workers only produce intermediate goods, but do not observe intermediate goods prices.

When workers in a particular intermediate goods firm, say 1, observe a shock to the relative prices of X and Y, say which raises P_x and lowers P_y, they do not know how that affects the value of their marginal value product because they do not know whether X or Y is intensively using the output K_1 which they produce. Note however when relative prices are not very dispersed, it does not matter as far as the workers' marginal value product is concerned whether X or Y is using K_1 intensively. We are thus able to derive a model where an observed increase in the dispersion of relative final goods prices causes an increase in the uncertainty workers have about their own marginal value product. That is, when workers observe the prices of the goods they consume but not the prices of the goods they produce, then an increase in the dispersion of observed consumption goods prices will increase the uncertainty workers have about the prices of the goods they produce. This model where workers know more about general economy conditions than about the conditions in their own industry is the reverse of Lucas' (1972) assumption that workers know more about their own firm's price than they know about the economy wide price level.

Using the results of Sections 2 and 3, Section 4 shows that an increase in the dispersion of relative prices which would leave the complete information Walrasian equilibrium unchanged, causes a fall in employment under the above asymmetric information situation. This is proved under the assumption that *ex ante*, workers and firms write an optimal labor contract which appropriately conditions on everything which will be observable to both parties. Therefore, the contractionary effect of aggregate shocks occurs despite the fact that contracts are conditioned on these shocks. This is in contrast to models such as Taylor (1980) or Blanchard (1979) where observable shocks affect output because wage contracts could not be conditioned on those shocks.

Section 5 contains our interpretations, conclusions and some references to evidence. In particular we suggest the importance of publicly observed but unanticipated changes in the price level (or rate of inflation) in a monetary economy. When a large percentage of individual wealth is held in the form of nominally denominated assets or liabilities, then changes in the price level will case a redistribution of wealth between nominal borrowers and nominal lenders. This wealth redistribution can be the source of shocks to the relative demands for goods if borrowers and lenders have different tastes. Output can contract as a consequence of the relative price dispersion created by the wealth redistribution. A wealth redistribution which would have no effect on total employment when agents have symmetric information, will cause employment to fall when they are asymmetrically informed.

2. The Optimal Employment Contract

We begin by analyzing the optimal contract between a single firm and its workers. It is convenient to begin without distinguishing physical productivity shocks from relative demand shocks. Thus we let $\tilde{s}$ be the random variable which is the source of variability in the marginal value product of labor, i.e., output q is given by

$$q = sf(\ell) , \tag{2.1}$$

where ℓ is total employment at the firm and $f(\ )$ is a strictly concave differentiable production function. It is useful to consider q as "real output".

In order to analyze the effect of public information on the optimal employment contract, we make the following conventions: There is an initial date 0 at which time the firm and worker have the same information, and neither party knows s. At date 1 the firm observes s and the workers do not. However the workers observe a signal n which gives them some information about s. The firm also observes n at date 1. The firm chooses ℓ at date 1 after it observes n and s. The workers observe ℓ, so that the total wage bill w can be made a function of both n and ℓ. We assume that q is not observed by the workers, so that n and ℓ are the only pieces of information on which wages can be conditioned.

We assume that labor is supplied perfectly elastically at a real wage rate of R per unit at date 1, i.e., we assume that a worker's utility of real income I and labor is given by $U(I-R\ell)$ where U is concave. We let $\overline{U}_0$ be the expected utility as of time 0 that a worker can get if he does not work at the particular firm which we are considering. It is notationally convenient to assume that there is only one potential worker for this firm. In Grossman and Hart [1981, p.304] we showed that all real values are unaffected if there are many workers and the firm can give layoff pay to those workers who are laid off.

An optimal contract involves a wage rule $w(\ell, n)$ and an employment rule $\ell(s,n)$ which maximizes the firm's expected utility subject to the worker's expected utility being at least as large as $\overline{U}_0$. Note that since s is not directly observable to the worker, the contract must make it optimal for the firm to actually choose $\ell(s,n)$ and $w(\ell,n)$ when the true state is s. This will be true if for each $s, \hat{\ell}, n$:

$$(2.2) \qquad sf(\ell(s,n)) - w(\ell(s,n),n) \geq sf(\hat{\ell}) - w(\hat{\ell},n) \ .$$

That is, $\ell(s,n)$ is the employment rule induced by the wage contract $w(\ell,n)$.[1/] For reasons explained in Grossman and Hart [1981,1982] we assume that the owners of the firm are risk averse and have a utility of profit $V(q-w)$, where V is strictly concave. Thus an optimal contract is $w(\ell,n)$, $\ell(s,n)$ which

(2.3) maximizes $E\, V(\tilde{s}f(\ell(\tilde{s},\tilde{n})) - w(\ell(\tilde{s},\tilde{n}),\tilde{n})$ subject to (2.2) and

$$E\, U(w(\ell(\tilde{s},\tilde{n}),\tilde{n}) - R\ell(\tilde{s},\tilde{n})) \geq \overline{U}_0. \tag{2.4}$$

Note that the expectation is with respect to the joint distribution of $\tilde{s}$ and $\tilde{n}$ which is assumed to be known to both the firm and worker at time 0. We are using a tilde over a variable to signify that it is a random variable.

It is convenient to define the complete information employment rule. If s were observed by the worker then an optimal employment contract would involve setting the marginal product of labor equal to the marginal disutility of effort R, and choosing the wage bill so that risk is optimally shared between the firm and workers. We denote this complete information rule by $\ell^*(s)$, given by

$$sf'(\ell^*) = R . \tag{2.5}$$

In Grossman-Hart (1981) we showed that when the worker has no information $\tilde{n}$ about the realization of $\tilde{s}$, then the optimal contract will involve an employment function $\ell(s)$ which is everywhere below $\ell^*(s)$. We now show the results of that paper can be applied to the situation here where workers can observe n at time 1.

<u>Proposition 1.</u> If $\ell^o(s,n)$, $w^o(\ell,n)$ form an optimal contract, i.e. (2.2) - (2.4) hold, then $\ell^o(s,n) \leq \ell^*(s)$ for all s and n.

Furthermore, if for given n either (a) the conditional distribution of s is continuous with support $[\underline{s},\overline{s}]$, or (b) it is a two-point distribution and the worker is sufficiently nearly risk neutral, then $\ell^{o}(s,n) < \ell^{*}(s,n)$ almost surely for these values of s less than $\overline{s}$ and for which $\ell^{*}(s,n) > 0$.

Proof. Let $\overline{U}(n) \equiv E[U(w^{o}(\ell^{o}(\tilde{s},n),n) - R\ell^{o}(\tilde{s},n))|n]$.

For each n consider the problem of choosing an optimal wage, and employment schedule $w(\ell;n)$ $\ell(s;n)$ which

$$(2.6) \qquad \text{maximizes} \qquad E[V(\tilde{s}f(\ell(\tilde{s};n)) - w(\ell(\tilde{s};n);n) \mid n]$$

subject to:

$$(2.7) \qquad E[U(w(\ell(\tilde{s};n);n) - R\ell(\tilde{s};n)) \mid n] \geq \overline{U}(n)$$

$$(2.8) \qquad sf(\ell(s;n)) - w(\ell(s;n);n) \geq sf(\hat{\ell}) - w(\hat{\ell};n) \quad \text{for all } s,\hat{\ell} .$$

All expectations are taken with respect to the conditional distribution of $\tilde{s}$ given that $\tilde{n} = n$. Note that $w^{o}(\ell,n)$ and $\ell^{o}(s,n)$ must be a solution to this problem. For if for some $\overline{n}$ there is a contract $w(\ell\ ;\overline{n}),\ell(s;\overline{n})$ which makes the objective in (2.6) larger, then the objective in (2.3) could be made larger by changing to $w(\ell;\overline{n})$, $\ell(s;\overline{n})$ from $w^{o}(\ell,\overline{n})$, $\ell^{o}(s,\overline{n})$ at $n = \overline{n}$. Since (2.7) holds, (2.4) would hold for the new contract. Note that (2.2) is identical to (2.8).

Note that with n fixed the problem in (2.6) - (2.8) is exactly the one that was solved in Grossman-Hart [1981]. There we assumed that both workers and firms had a given distribution on $\tilde{s}$, say G, and chose a $w(\ell)$, $\ell(s)$ contract to maximize EV subject to $EU \geq \overline{U}$ and $sf(\ell)-w(\ell) \geq sf(\hat{\ell})-w(\hat{\ell})$ for all $s,\hat{\ell}$. The solution to that problem depends on the distribution of s, namely G. We could have noted this explicitly by writing $w(\ell;G)$, $\ell(s;G)$, but this would have been unnecessary since we kept G fixed. The problem in (2.6)-(2.8) notes the dependence of the contract on information explicitly. Since for each n this problem is equivalent to that solved in Grossman and Hart [1981], it follows that $\ell^{o}(s,n) \leq \ell^{*}(s,n)$. Proofs of the statements in (a) and (b) regarding strict inequality appear in the text below, and footnotes 2 and 3. QED

The idea behind the Proposition is as follows. We can _imagine_ that at time 1 the worker and firm observe the realization of $\tilde{n}$ before the firm observes the realization of $\tilde{s}$. Given that $\tilde{n} = n$, this induces a conditional probability distribution on $\tilde{s}$, say $F(s|n)$. We then _imagine_ that the firm and worker reopen their contract and negotiate an employment and wage rule which maximizes the firm's expected utility conditional on the information n, and which gives the worker a value of conditional expected utility $\overline{U}(n)$ which was preassigned at time 0. This contract is for each n exactly like the one in Grossman-Hart (1981).

A simple example is one where $\tilde{n}$ takes on two possible values n_a, and n_b. When $n = n_a$ then $s = s_a$ for sure, so there is no uncertainty. On the other hand when $n = n_b$, s has a continuous distribution function on $[\underline{s},\overline{s}]$. Clearly the conditionally optimal contract at n_a is the full information one $\ell^{*}(s_a)$ - since there is no uncertainty. On the other hand when $n = n_b$ we can appeal to Grossman-Hart [1981,p.305] to state that if $V'' < 0$ then $\ell(s,n_b) < \ell^{*}(s)$ for almost all $s \in [\underline{s},\overline{s})$ and $\ell(\overline{s},n_b) = \ell^{*}(\overline{s},n_b)$. That is, as long as s is not the highest possible, the optimal contract will with probability one involve an employment level strictly less than that of the full information contract. Equivalently the marginal wage $\frac{\partial w}{\partial \ell}(\ell,n) > R$, for $\ell < \ell^{*}(\overline{s})$.[2/]

Another case of interest is where n also takes on two values, with n_a indicating that $s = s_a$ as before. However now suppose that n_b indicates that only m possible value values of s have positive probability, say $s_1, s_2, \ldots, s_m$. An argument similar to that given in Grossman-Hart [1982] or Azariadis [1982] can be used to show that $\ell(s_i, n_b) \leq \ell^*(s_i)$. Further, it will generally be the case that $\ell(s_i, n_b) < \ell^*(s_i)$, except for the largest s_i. For example if $m = 2$ and the worker is only slightly risk averse, then the employment inequality will be strict for the lower value of s.[3/]

In the sections which follow we will assume that $\ell(s,n) < \ell^*(s)$ when s is less than the largest possible realization of $\tilde{s}$, and when n imparts incomplete information about $\tilde{s}$.

3. General Equilibrium With Physical Productivity Shocks

In the last section we reviewed our model of the optimal employment contract when workers receive incomplete information about their productivity. In this section we give the simplest possible general equilibrium model for an economy which is subject to shocks. We assume that workers know that the economy has received a shock, but that they don't know how the shock affects their own firm. In this model, aggregate unemployment will rise because an economy wide shock increases the perceived variability of a worker's marginal physical productivity.

We assume that firm i has a production function given by

$$q_i = s_i f(\ell_i) \quad . \tag{3.1}$$

To illustrate our basic idea imagine that there is a steady state where firms earn no rents. In this steady state all firms would have the same profitability from employing labor. Hence $s_1 = s_2 = \ldots$. Now imagine that the economy is hit by a shock. This shock will hurt some firms more than others. That is, it induces a non-degenerate distribution of $\tilde{s}$ across firms . We assume that the owner of the firm knows how his s is affected, but that the workers only know the cross sectional distribution. Lacking any further knowledge the workers assume that their own firm's productivity is a random drawing from that cross sectional distribution.

In the notation of the previous Section let $\tilde{n}$ be the signal observed by firms and workers about the economy wide shock. Let

$F(s|n)$ be the cross sectional distribution of productivities associated with the news $\tilde{n} = n$. It is convenient to have a notation for the news that no shock has occurred. We denote the news by $\tilde{n} = n^*$, and let all firms have $s = s^*$ in that "steady state" situation:

$$(3.2) \qquad \Pr(s^*|n^*) = 1 .$$

Further, to model the idea that shocks lead to a cross-sectional dispersion in s, assume that if $\tilde{s}$ is a discrete random variable, then

$$(3.3) \qquad \Pr(\tilde{s} = s_i|\tilde{n} = n) \neq 1 \quad \text{for} \quad n \neq n^* \quad \text{and all} \quad s_i .$$

As an example of the above notation, consider the case where there are two types of firms. Consider three possible pairs of productivities for the firms: $(s_1, s_2) = (1/2, 1/2)$ or $(1/3, 2/3)$ or $(2/3, 1/3)$. In the first situation $s_1 = s_2$ so there is no cross sectional dispersion; this corresponds to the news $\tilde{n} = n^*$. In the second situation type 1 firms are adversely affected relative to type 2 firms, while in the third situation type 2 firms are adversely affected. We assume that the worker in each firm knows the type of his firm but lacks the information to distinguish between the second and third situations. That is, workers receive a signal $\tilde{n} = n_b$, such that, for example each of the latter two situation are equally likely. If this is the only news received then

$$\Pr(\tilde{s} = \tfrac{1}{2}|n^*) = 1, \; \Pr(\tilde{s} = 1/3|n_b) = \Pr(\tilde{s} = 2/3|n_b) = 1/2 .$$

Note that in both situation 2 and situation 3 workers observe the same signal $\tilde{n} = n_b$. It is not crucial to our analysis that the workers in all firms know only that their firm's s_i is a random draw from the cross sectional distribution $F(s|n)$. Only notational complexity would be added to what follows if we subscripted F with an i, as long as the $\tilde{n}$ shocks which increase a given worker's uncertainty about his firm's productivity also are associated with a greater cross sectional dispersion of $\tilde{s}$.

It is useful to define the Walrasian (or complete information) level of employment which would be associated with a particular cross sectional distribution of the s_i. Under complete information, when workers have a utility of income I and labor ℓ given by $U(I-R\ell)$, employment would be given by

$$sf'(\ell^*) = R . \tag{3.4}$$

This defines the employment level $\ell^*(s)$. If the worker in firm i observes s_i, then he will write a contract with the firm agreeing to supply $\ell^*(s_i)$ when the firm's $\tilde{s} = s_i$. The firm will agree to pay a level of total wages $w(s_i)$ which shares risk by equating the firm's and worker's marginal rate of substitution across states (i.e., there is some number γ such that $V'(s_i f(\ell^*(s_i)) - w(s_i)) = \gamma\, U'(w(s_i) - R\ell^*(s_i))$ for all s_i). Thus for any given cross sectional distribution of $\tilde{s}$, $F(s|n)$, total economy wide employment $L^*(n)$ is given by

$$L^*(n) = E[\ell^*(\tilde{s})|\tilde{n}] \equiv \int_{\underline{s}}^{\bar{s}} \ell^*(s)\,dF(s|n) \quad , \tag{3.5}$$

where we maintain the assumption throughout that $\underline{s} \leq s \leq \overline{s}$ are the bounds on realizations of $\tilde{s}$.

For the no shock signal n^* in (3.2) employment is

$$L^* \equiv L^*(n^*) = \ell^*(s^*) \quad . \tag{3.6}$$

In general there will be many cross sectional distribution of $\tilde{s}$, $F(s|n)$ which keep $L^*(n) = L^*$. There is no reason why increasing s in some industries and decreasing s in others, should lead the Walrasian level of total employment to fall. We will see that under asymmetric information this is not the case : shocks which cause dispersion, represented by n different from n^*, will tend to lead to a decrease in total employment.

As we noted in Section 2, if s_i cannot be observed by the worker in firm i, but his employment ℓ_i and the signal n are observed, then the wage bill can depend only on ℓ_i and n:$w^o(\ell_i,n)$. Proposition 1 allowed us to appeal to an earlier result to show that for an optimal employment contract when $\tilde{s}$ is not degenerate,

$$\ell^o(s,n) < \ell^*(s) \quad \text{for} \quad n \neq n^* \quad \text{and} \quad s < \overline{s}. \tag{3.7}$$

We can define the economy's total employment under asymmetric information, given that $\tilde{n} = n$, by

$$L^o(n) = E[\ell^o(s,n)\,|\,n] = \int_{\underline{s}}^{\overline{s}} \ell^o(s,n)\,dF(s|n) \quad . \tag{3.8}$$

An immediate implication of (3.7) is that $L^o(n) < L^*(n)$ for $n \neq n^*$. That is, when the economy suffers no $\tilde{s}$ shock so that there is no dispersion of s across firms $L^o(n^*) = L(n^*)$, but when dispersion occurs this creates asymmetric information and employment falls below the Walrasian level. (Of course, if the shock is permanent then there will be a flow of resources from the adversely affected industries to the benefically affected industries, so that in the long run the returns in the various sectors are equalized, i.e., $s_i f(\ell_i)-R\ell_i = s_j f(\ell_j)-R\ell_j$))1/

It is interesting to note that a type of multiplier occurs for some types of dispersion changes. In particular, suppose the sources of dispersion are such that $L^*(n) = L^*$ for <u>all</u> n. Then since $L^o(n) < L^*(n)$, an aggregate shock always lowers employment relative to the value of employment with no shock, i.e., $L^o(n) < L^o(n^*) = L^*$. Further if we choose some measure of dispersion for the cross sectional distribution of marginal products which is continuous, then employment will be a monotonically decreasing function of dispersion near the point of no dispersion. That is, suppose that $\tilde{n}$ has two components $\tilde{n}_1$ and $\tilde{n}_2$, so $\tilde{n} = (\tilde{n}_1,\tilde{n}_2)$, and $E[\ell^*(\tilde{s},\overline{n}_1,n_2)|\tilde{n}_1 = \overline{n}_1, \tilde{n}_2 = n_2] = L^*$ for some value of $\overline{n}_1$ say n_1 and all values of n_2. Thus n_1 is news about the level of Walrasian employment. Suppose that n_2 represents information about the variance of the Walrasian employment, i.e., $\sigma(n_2) = \mathrm{Var}(\ell^*(\tilde{s},\overline{n}_1,n_2)|\tilde{n}_1 = \overline{n}_1, \tilde{n}_2 = n_2)$ is monotone increasing in n_2 and equal to zero at say $n_2 = n_2^*$. Then our previous statements imply that $L^o(\overline{n}_1,n_2)$ will be a monotone decreasing function of $\sigma(n_2)$ say $\overline{L}(\sigma(n_2))$, with $\overline{L}(0) = L^*$, in a neighborhood of $\sigma(n_2) = 0$.

It is important to note that the aggregate level of employment is not a useful signal to the workers given that they already observe n. The aggregate level of unemployment does not tell each worker how his particular firm has been shocked, it only reveals something about the dispersion of s across firms. Alternatively, workers who observe the aggregate unemployment rate do not have complete information because knowledge of how an aggregate variable is affected will not tell them how their own firm is affected. Thus our model is fundamentally different from that of Lucas [1972]. There it is assumed that people know their own situation much better than economy wide values. We have assumed the reverse: shocks are such that workers know more about the economy wide variable $L(n)$, than they know about their own firm's productivity. Thus Lucas' model would yield no unemployment when the aggregate level of unemployment is observable while our model does yield unemployment in such cases.[2/]

4. Relative Demand Shocks

In this Section we consider a model with many commodities where relative demand shocks cause uncertainty about labor's marginal product in a particular firm. An important shock hitting the economy are changes in the price level (i.e., the price of goods in terms of money). Observed changes in the price level which are not anticipated cause a redistribution of wealth between nominal borrowers and nominal lenders. To the extent that all borrowers and lenders do not have the same homothetic utility functions for goods, the wealth redistribution will cause a change in relative prices. To the extent that workers do not know how the observed change in the wealth distribution affects their own firm this will cause an increase in uncertainty about their marginal value product. We can apply an analysis similar to that given in the previous Section to show that aggregate employment will decrease more under optimal asymmetric information contracts, than it would in a Walrasian model.

There are a number of difficulties in developing the above model. One problem with modeling the effect of unanticipated price changes on relative demands is that we should make an explicitly dynamic model of the economy and put in some use for money. We expect to do that in future work, but here will show, for a non monetary static economy, how a redistribution of wealth will lead to larger changes in employment than would occur in a Walrasian model. We will simply analyze the effect of changes in the distribution of endowment wealth across consumers, in a multigood economy, under asymmetric information.

Another problem is that it is difficult to model asymmetric information about relative demand shocks in a competitive economy. If a firm operates in a competitive product market then its demand is completely summarized by the price of the product it sells relative to all other prices. If workers buy the products sold by firms then they will observe the prices and cannot have imperfect information about each firm's demand.[1/]

To get around the above problem we assume that some firms produce intermediate goods at prices which consumers do not observe. Further a worker does not know how a change in the demand for a final consumption good affects the demand for the particular intermediate good produced by his firm. As in the last Section it is useful to assume that the only thing a worker knows about the price his firm receives is that the price is a random drawing from the current cross-sectional distribution of intermediate good prices which other firms are receiving. We make the further assumption that the cross-sectional distribution of intermediate good prices is the same as that of final consumer goods. We now show that it is possible to construct a technology of intermediate and final goods with the above properties.

Let there be two produced final (i.e. consumption) goods X and Y. Let there be two intermediate goods K_1 and K_2. There are firms which use labor and competitively produce good K_1 ("type 1 firms"), and other firms which competitively use labor to produce good K_2 ("type 2 firms"). Both types of firms have the production function $F(\cdot)$ of the previous Section.

Each final good is competitively assembled <u>without the use of labor</u> according to the following linear production technology

(4.1) $$X = (1 - \theta)K_1 + \theta K_2$$

(4.2) $$Y = \theta K_1 + (1 - \theta)K_2 \quad ,$$

where θ is the realization of a random variable $\tilde{\theta}$. We assume that

(4.3) $0 < \tilde{\theta} < 1$ and $\tilde{\theta}$ is symmetric about $1/2$.

When $\theta > 1/2$, industry Y finds K_1 more productive than K_2, while industry X finds that the reverse is true. The opposite is the case when $\theta < 1/2$. We will show that when $\theta > 1/2$ industry Y will utilize only K_1 and industry X will utilize only K_2. Thus when $\theta > 1/2$ an increase in the final demand for X will be good for type 2 firms. When $\theta < 1/2$, an increase in final demand for X will be good for type 1 firms. Thus changes in final demand have benefits for workers which depend on the realization of $\tilde{\theta}$.

We assume that there is a third consumption good Z which is not produced by current goods or current labor, but some consumers have an endowment of it. We normalize the price of Z to be 1. For the rest of this Section all prices are measured in terms of Z. Let v_i be the price of intermediate good K_i. Let P_x and P_y be the prices of X and Y respectively.

There are two cases to consider:

Case (1) $\theta < 1/2$.

In this case equilibrium involves industry X specializing in the utilization of K_1 and Y specializing in K_2. This is because

$$\frac{\theta}{1-\theta} < \frac{1-\theta}{\theta} \tag{4.4}$$

so $\frac{v_2}{v_1} > \frac{1-\theta}{\theta}$ would imply that neither firm would demand the output of type 2 intermediate goods. From what follows it will be clear that some of K_2 must be supplied, which is only possible (given no demand for it) if $v_2 = 0$. Similarly if $\frac{v_2}{v_1} < \frac{\theta}{1-\theta}$ the same follows for good K_1. Hence

$$\frac{\theta}{1-\theta} \leq \frac{v_2}{v_1} \leq \frac{1-\theta}{\theta} \quad . \tag{4.5}$$

Further if X and Y are produced then their respective prices must be given by their unit resource cost

$$v_1 = P_x(1-\theta), \quad v_2 = P_y(1-\theta) \quad \text{when} \quad \theta < \frac{1}{2} \quad . \tag{4.6}$$

Case (2) $\theta > 1/2$.

A symmetric argument shows that

$$\frac{1-\theta}{\theta} \lesssim \frac{v_2}{v_1} \le \frac{\theta}{1-\theta} \tag{4.7}$$

and

$$v_1 = P_y\theta, \quad v_2 = P_x\theta \qquad \text{when} \quad \theta > 1/2 \; . \tag{4.8}$$

In either Case, for each realization of $\tilde{\theta}$, the cross-sectional distribution of (v_1,v_2) is the same as that of (P_x,P_y). That is, if $P_x = P_y$ then $v_1 = v_2$, and if some P_x is say 30% of P_y then v_1 will be 30% of v_2. Thus for each θ, if there is a shock to the relative demand for X vs Y, and this causes a large relative price differential with say $P_x > P_y$. then v_1 and v_2 will be very different. A worker who could observe the <u>distribution</u> of intermediate goods prices, would have very poor information about his own firm's price when P_x is much larger than P_y, while he would have perfect information about his firm's price when $P_x = P_y$.

A worker who works in the K_1 industry does not know v_1 or v_2. He only knows P_x and P_y. When $P_x = P_y = P$ he knows that $v_1 = v_2 = P\theta$ if $\theta > 1/2$. Thus in the case where $\tilde{\theta}$ take on exactly two values , say $\tilde{\theta} = \frac{1}{2} + b$ or $\tilde{\theta} = \frac{1}{2} - b$, it will be the case that $P_x = P_y$ implies that $v_1 = v_2 = P(\frac{1}{2} + b)$ irrespective of whether $\tilde{\theta} < 1/2$ or $\tilde{\theta} > 1/2$. When $\tilde{\theta}$ takes only two values, (4.6) and (4.8) yield

$$v_1 = \begin{cases} P_x(\frac{1}{2} + b) & \text{if} \quad \theta < 1/2 \\ P_y(\frac{1}{2} + b) & \text{if} \quad \theta > 1/2 \end{cases} \tag{4.9a}$$

(4.9b)
$$v_2 = \begin{cases} P_y(\frac{1}{2} + b) & \text{if } \theta < 1/2 , \\ P_x(\frac{1}{2} + b) & \text{if } \theta > 1/2 \end{cases}$$

Therefore, since a worker in firm 1 observing P_x and P_y does not know θ, his uncertainty about v_1 is measured by $P_x \div P_y$. Further the cross sectional distribution of final goods prices multiplied by the constant $(.5+b)$ is the same as that of intermediate goods prices.

Thus in the case where $\tilde{\theta}$ takes on only 2 values knowledge of (P_x, P_y) is exactly the same as knowledge of the cross sectional distribution of v_i. The reader is cautioned that a worker who knows the cross sectional distribution of the v_i does not know his own firm's price unless that distribution is degenerate.[2/] For simplicity of exposition we will deal only with the case where $\tilde{\theta}$ takes on two values.

It is now possible to model the optimal labor contracts for the workers in the intermediate good industries. From (3.9) a worker who observes P_x and P_y, thinks that his firm's v is a random drawing, from the cross sectional distribution of v's which we denote by $\tilde{v}$, satisfying

(4.10)
$$\tilde{v} = \begin{cases} P_x(.5 + b) & \text{with probability } 1/2 \\ P_y(.5 + b) & \text{with probability } 1/2 \end{cases}$$

Thus using the notation of the previous Section the news n is the particular prices P_x and P_y.

The form of the optimal labor contract will depend on firms' and workers' preferences. We make the following assumptions:

Workers and Firms in the Intermediate Goods Industries.

All workers are assumed to be identical and to have ordinal preferences represented by the utility function $X^{\lambda_1}Y^{\lambda_2}Z^{\lambda_3} - RL$, where R is the marginal disutility of effort and $\lambda_i \geq 0$ for all i, and $\lambda_1 + \lambda_2 + \lambda_3 = 1$. Firms' owners are assumed to have the same tastes for consumption goods as workers and they have the utility functions $X^{\lambda_1}Y^{\lambda_2}Z^{\lambda_3}$. The total worker and firm demand for X and Y is given by

$$X^d = \frac{\lambda_1}{P_x}(I_w + I_F) \qquad Y^d = \frac{\lambda_2}{P_y}(I_w + I_F)\ . \tag{4.11}$$

Define $\delta \equiv \lambda_1^{\lambda_1}\lambda_2^{\lambda_2}\lambda_3^{\lambda_3}$. Thus the indirect utility functions of workers and firms are respectively

$$\delta\, P_x^{-\lambda_1}P_y^{-\lambda_2}I_w - R\ell, \qquad \delta\, P_x^{-\lambda_1}P_y^{-\lambda_2}I_F \tag{4.12}$$

The income of workers plus firms automatically nets out wage payments, so it is given by the total income from production of intermediate goods plus their endowments of the non produced good e_1:

$$I_w + I_F = v_1K_1 + v_2K_2 + e_1 = P_xX + P_yY + e_1\ . \tag{4.13}$$

Let e_{1F}, e_{1w} be the part of e_1 owned by firms and workers respectively. Note that the production of final goods from intermediate goods generates no *ex post* profit in any state of nature, by the linear technology assumption.

We model the economy as if there are 2 dates 0 and 1. At date 0 the workers and firms meet to sign a contract. They know neither θ nor what P_x and P_y will be realized, but they know the distribution of these variables. Furthermore we assume that the distribution of (P_x,P_y) is symmetric; this, coupled with our assumption that the distribution of θ is symmetric around 1/2 , implies that workers are indifferent about signing contracts with K_1 firms vs K_2 firms. Let n denote (P_x,P_y). Then workers and firms write a contract which makes the wage bill paid at date 1 a function $w(\ell,n)$. At date 1 the firm observes θ and its own price v and n, while the worker observes only ℓ and $n \equiv (P_x,P_y)$. Finally, in the initial period the attitudes to risk of firms and workers are represented by Von Neuman-Morgenstern utility functions defined over final period consumption, given by $V(X^{\lambda_1}Y^{\lambda_2}Z^{\lambda_3})$ and $U(X^{\lambda_1}Y^{\lambda_2}Z^{\lambda_3} - RL)$ respectively. We assume that U is concave and that V is strictly concave. To simplify matters, we assume that there are equal numbers of workers and firms. Thus in equilbrium each firm makes a contract with exactly one worker at date 0.

Other Consumers

There are other consumers who do not work or own intermediate goods' firms. These consumers' only source of wealth is their endowment of the non produced good e_2. These consumers have Cobb Douglas utility functions but with a different parameter from firms or workers. Their parameters are $\gamma_1, \gamma_2, \gamma_3$. Their demands are

$$(4.14) \qquad X_0^d = \frac{\gamma_1}{P_x} e_2 \qquad\qquad Y_0^d = \frac{\gamma_2}{P_y} e_2 \quad .$$

The only role of the "other consumers" is to generate changes in relative prices due to changes in the wealth distribution. We could have considered a wealth redistribution between firms and workers, but it is more difficult to characterize the optimal labor contract when workers and firms have different tastes for consumer goods.

Equilibrium

Let $e \equiv (e_1, e_2)$. In equilibrium consumption prices $n \equiv (P_x, P_y)$ will be a function of e. In turn, intermediate goods prices are functions of n and θ given in (4.9). Thus, given the distribution of n and θ, the optimal labor contract $w_i(\ell, n)$, $\ell_i(v_i, n)$ for firms in industry i

$$(4.15) \quad \text{maximizes} \qquad E\, V\left(\frac{v_i f(\ell_i(\tilde{v}_i, n)) - w_i(\ell_i(\tilde{v}_i, \tilde{n}), \tilde{n}) + e_{1F}}{\delta^{-1}\, \tilde{P}_x^{\lambda_1} \tilde{P}_y^{\lambda_2}}\right)$$

subject to

$$(4.16) \qquad \ell_i(v_i, n) \;\; \underset{\ell_i}{\text{maximizes}} \qquad v_i f(\ell_i) - w_i(\ell_i, n) \quad \text{for each } n,$$

$$(4.17)\qquad E\,U\left(\frac{w_i(\ell_i(\tilde{v}_i,\tilde{n}),\tilde{n}) + e_{1w}}{\delta^{-1}\,\tilde{P}_x^{\lambda_1}\,\tilde{P}_y^{\lambda_2}} - R\ell_i(\tilde{v}_i,\tilde{n})\right) \geq \bar{U}\ .$$

The expectation in (4.15) and (4.17) is taken as of the initial period over the prospective market clearing prices $P_x(e)$, $P_y(e)$ and $v_1(e,\theta)$, $v_2(e,\theta)$.

Note that, for a given realization of the public information $n \equiv (P_x,P_y)$ and the private information $\tilde{\theta}$, there will be lucky firms and unlucky firms. For example, if $P_x > P_y$ and $\tilde{\theta} > 1/2$, then from (4.9) firms in intermediate goods industry 1 will receive a higher price for their output $(v_1 = (1/2 + b)P_x)$ than firms in industry 2 $(v_2 = (1/2 + b)P_y)$-- that is, labour is more profitable in industry 1 than in industry 2, while if $\tilde{\theta} < 1/2$ the opposite is true. The firms know whether they are lucky or not, i.e. whether $\tilde{\theta} > 1/2$ or $\tilde{\theta} < 1/2$, but the workers know only, given n, that their firm's v is drawn from the distribution specified in (4.10). The conditional distribution of $\tilde{v}$ given n is analogous to the conditional distribution $F(s|n)$ in Section 3. One difference is that in this section workers and firms are interested in real income $\dfrac{\delta I}{P_x^{\lambda_1} P_y^{\lambda_2}}$ rather than just income I measured in terms of good Z. Note that, given n, P_x, P_y are determined, and hence maximizing profit measured in terms of Z $v_i f(\ell_i) - w_i(\ell_i,n)$ in (4.16) is equivalent to maximizing real profit

$$\delta\left[\frac{v_i f(\ell_i) - w(\ell_i,n)}{P_x^{\lambda_1}\,P_y^{\lambda_2}}\right]\ .$$

Note that at date 0, when contracts are signed, type 1 and 2 firms face the same probability distribution of profit. Thus the form of the optimal contract will be the same for the two types of firms. From now on, we will therefore drop the subscript i and refer to the optimal contract as a pair $w(L,n)$, $L(v,n)$.[3/]

In equilibrium P_x, P_y must be spot market clearing prices at date 1. This means, in view of (4.11), (4.13), (4.14), that

$$\frac{\lambda_1}{P_x}(P_x X + P_y Y + e_1) + \frac{\gamma_1}{P_x} e_2 = X, \tag{4.18a}$$

$$\frac{\lambda_2}{P_y}(P_x X + P_y Y + e_1) + \frac{\gamma_2}{P_y} e_2 = Y, \tag{4.18b}$$

where X,Y are outputs of the two produced goods. Multiplying both sides of each equation by the respective prices and eliminating produced good income yields

$$X = \frac{E_x}{P_x} \qquad Y = \frac{E_y}{P_y} \quad , \tag{4.19}$$

where E_x and E_y are given by

$$E_x \equiv e_1\left[\frac{\lambda_1}{\lambda_3}(\lambda_1+\lambda_2) + \lambda_1\right] + e_2\left[\frac{\lambda_1}{\lambda_3}(\gamma_1+\gamma_2) + \gamma_1\right] \tag{4.20a}$$

$$E_y \equiv e_1\left[\frac{\lambda_2}{\lambda_3}(\lambda_1+\lambda_2) + \lambda_2\right] + e_2\left[\frac{\lambda_2}{\lambda_3}(\gamma_1+\gamma_2) + \gamma_2\right] . \tag{4.20b}$$

Note that when the $\lambda_i = \gamma_i$, changes in the distribution of nonproduced wealth have no effect on E_x or E_y, and thus have no effect on relative prices.

It is convenient to use the notation L_x and L_y for the employment in the industry which produces the intermediate goods used exclusively by X and Y respectively. That is, from (4.9),

$$L_x = L_1(v_1,n) = L_1((\frac{1}{2} + b)P_x,n), \; L_y = L_2(v_2,n) = L_2((\frac{1}{2} + b)P_y,n) \quad \text{when} \quad \theta < \frac{1}{2},$$

and

$$L_y = L_1(v_1,n) = L_1((\frac{1}{2} + b)P_y,n), \; L_x = L_2(v_2,n) = L_2((\frac{1}{2} + b)P_x,n) \quad \text{when} \quad \theta > \frac{1}{2} .$$

Since $L_1(v,n) = L_2(v,n)$, this simplifies to

(4.21a) $$L_x = L((\frac{1}{2} + b)P_x,n), \quad L_y = L((\frac{1}{2} + b)P_y,n) \quad .$$

Also outputs X and Y are given by

$$X = (1 - \theta)K_1 = (1 - \theta)f(L_x), \quad Y = (1 - \theta)K_2 = (1 - \theta)f(L_y) \quad \text{if} \quad \theta < \frac{1}{2} ,$$

$$X = \theta K_2 = \theta f(L_x), \; Y = \theta K_1 = \theta f(L_y) \quad \text{if} \quad \theta > \frac{1}{2} .$$

Since $\theta = \frac{1}{2} - b$ or $\frac{1}{2} + b$, this simplifies to

(4.21b) $$X = (\frac{1}{2} + b)f(L_x), \quad Y = (\frac{1}{2} + b)f(L_y) \quad .$$

Conditions (4.15)-(4.17), (4.19) and (4.21) characterize a contract equilibrium under asymmetric information. The way to think of this equilibrium is as follows. There is an exogenously given probability distribution of the endowment vector $\tilde{e} = (\tilde{e}_1, \tilde{e}_2)$. In equilibrium there will be a price function $P(\tilde{e}) = (P_x(\tilde{e}), P_y(\tilde{e})$ which says what prices correspond to a particular realization of e. This in turn determines intermediate price functions $v_1(e,\theta), v_2(e,\theta)$ according to (4.9). Corresponding to this, there are optimal labor contracts in the two industries which are solutions to (4.15)-(4.17). These contracts in turn generate supplies of output, given in (4.21a) and (4.21b), for each realization of $n \equiv (P_x, P_y)$. Finally, for the system to be in equilibrium, these supplies must clear markets, i.e. satisfy (4.19), for each n.4/ 5/

It is useful to examine the Walrasian (or complete information equilibrium) as a function of $E \equiv (E_x, E_y)$. In a Walrasian Equilibrium wages in each industry are equalized to the marginal product of labor. This implies that the Walrasian equilibrium $\overline{P}_y, \overline{P}_x, \overline{\ell}_x, \overline{\ell}_y$ satisfy

$$(4.22) \qquad \frac{\delta\, v_x f'(\ell_x)}{\overline{P}_x^{\lambda_1} \overline{P}_y^{\lambda_2}} = \frac{\delta\, \overline{P}_x(.5 + b) f'(\overline{\ell}_x)}{\overline{P}_x^{\lambda_1} \overline{P}_y^{\lambda_2}} = R \ ;$$

$$(4.23) \qquad \frac{\delta\, v_y f'(\ell_y)}{\overline{P}_x^{\lambda_1} \overline{P}_y^{\lambda_2}} = \frac{\delta\, \overline{P}_y(.5 + b) f'(\overline{\ell}_y)}{\overline{P}_x^{\lambda_1} \overline{P}_y^{\lambda_2}} = R \ ;$$

$$(4.24) \qquad X = (.5 + b) f(\overline{\ell}_x) = \frac{E_x}{\overline{P}_x} \ ;$$

$$(4.25) \qquad Y = (.5 + b) f(\overline{\ell}_y) = \frac{E_y}{\overline{P}_y}$$

where (4.24) and (4.25) are equivalent to the condition that supply equals demand in the two final goods industries (see the derivation of (4.19)).

We now use Proposition 1 to show that there is less employment in the asymmetric information equilibrium than in the Walrasian Equilibrium when there is dispersion in goods prices. We have seen that, for a given realization of $n = (P_x, P_y)$, there will be a lucky intermediate goods industry and an unlucky intermediate goods industry (if $P_x > P_y$, industry 1 is lucky if $\tilde{\theta} > \frac{1}{2}$ and unlucky if $\tilde{\theta} < \frac{1}{2}$ and conversely for industry 2). Hence appealing to the result in Section 2, we see that a firm that is in the lucky industry will equate the marginal product of labor to the marginal disutility of effort, while a firm that is in the unlucky industry will set the marginal product of labor above the marginal disutility of effort. That is, in an asymmetric information equilibrium, when say $P_x \geq P_y$, employment will satisfy

(4.26) $$\frac{\delta P_x}{P_x^{\lambda_1} P_y^{\lambda_2}} (.5 + b) f'(\ell_x) = R$$

(4.27) $$\frac{\delta P_y}{P_x^{\lambda_1} P_y^{\lambda_2}} (.5 + b) f'(\ell_y) = R(1 + \alpha) \ ,$$

where $\alpha \geq 0$, and $\alpha = 0$ if and only if $P_x = P_y$. Note that in the asymmetric information equilibrium denoted by $P_x, P_y, \ell_x . \ell_y$ the supply of final goods equals their demand, i.e. (4.24) and (4.25) hold:

(4.28) $$(.5 + b)f(\ell_x) = E_x \div P_x$$

(4.29) $$(.5 + b)f(\ell_y) = E_y \div P_y$$

Thus the only difference between the asymmetric information equilibrium and the complete information equilibrium is the presence of α in (4.27).

We now show that if the distribution of wealth is such as to lead to prices which create uncertainty on the part of the workers about their marginal product then total employment is reduced below what it would be under complete information. Further the prices of both produced goods relative to the non produced good are higher than under complete information.[6/] Further the output of both industries will contract relative to the Walrasian level.

<u>Proposition 2:</u> If E_x and E_y generate a Walrasian equilibrium with prices say $\overline{P}_x > \overline{P}_y$ and employments $\overline{\ell}_x, \overline{\ell}_y$, then the asymmetric information equilibrium P_x, P_y, ℓ_x, ℓ_y will have the property that $P_x > \overline{P}_x$ $P_y > \overline{P}_y$ $\ell_x < \overline{\ell}_x$ and $\ell_y < \overline{\ell}_y$.

<u>Proof:</u> Comparing (4.28), (4.29) with (4.24) and (4.25) shows that it is necessary and sufficient to prove that $P_x > \overline{P}_x$ and $P_y > \overline{P}_y$. Suppose not. Define $P \equiv P_x^{\lambda_1} P_y^{\lambda_2}$, $\overline{P} \equiv \overline{P}_x^{\lambda_1} \overline{P}_y^{\lambda_2}$.

<u>case(a)</u> $P_x \leq \overline{P}_x$. Using the Supply = Demand condition (4.28) and (4.24), yields $\ell_x \geq \overline{\ell}_x$. Thus, the marginal productivity conditions (4.22) and (4.26), imply that

(4.30) $$P_x \div P \geq \overline{P}_x \div \overline{P} .$$

But since $P_x \leq \overline{P}_x$, this implies that $P_y \leq \overline{P}_y$. Supply = Demand implies that output of Y must be higher, so $\ell_y \geq \overline{\ell}_y$. But the marginal conditions (4.23) and (4.27) then imply that

(4.31) $$P_y \div P > \overline{P}_y \div \overline{P} .$$

Now raise (4.30) to the power λ_1, (4.31) to the power λ_2 and multiply. This yields $P > \overline{P}$, which is inconsistent with $P_x \leq \overline{P}_x$, $P_y \leq \overline{P}_y$.

Case (b) $P_y \leq \overline{P}_y$. Supply = Demand implies that $\ell_y \geq \overline{\ell}_y$. Then (4.27) and (4.23) imply that $P_y \div P \geq \overline{P}_y \div \overline{P}$. This must imply that $P_x \leq \overline{P}_x$. The contradiction now proceeds exactly as in case (a). QED

As in Section 3 we can show that the above Proposition implies that increases in the dispersion of final good prices, which in the Walrasian equilibrium would not affect total employment, will decrease total employment under asymmetric information (note that if there is no dispersion, i.e. $\overline{P}_x = \overline{P}_y$ then $\ell_x = \overline{\ell}_x$, $\ell_y = \overline{\ell}_y$ and so employment under asymmetric information equals employment under complete information which equals Walrasian employment). In particular, the

Walrasian equilibrium in (4.22)-(4.25) may be solved for prices and employment as a function of the distribution of endowments $e \equiv (e_1,e_2)$ using (4.20). Denote the solution by $\overline{P}_x(e_1,e_2)$, $\overline{P}_y(e_1,e_2)$, $\overline{\ell}(e_1,e_2) \equiv \overline{\ell}_x(e_1,e_2) + \overline{\ell_y}(e_1,e_2)$. Note that the distribution of endowment matters only if tastes are different among consumers, so we of course assume that $\lambda_1 \neq \gamma_1$ and $\lambda_2 \neq \gamma_2$ in such a way that E_x and E_y depend on e_1 and e_2. That is, assume that (E_x, E_y) is an invertible function of (e_1, e_2). In this case there will be a locus of values for E_x and E_y such that $\overline{\ell}(e_1,e_2) = \overline{\ell}$, where $\overline{\ell}$ is a constant. There will also be a locus of values where $\overline{P}_x(e_1,e_2) = \overline{P}_y(e_1,e_2)$. Clearly $\overline{\ell}$ can be chosen so the two loci intersect. These two loci will not be the same. That is, changes in the wealth distribution can be chosen which cause changes in relative demands such that (a) prices change, (b) some industries contract while others expand and (c) the Walrasian total level of employment is the same. From Proposition 2 we know that such changes will cause the level of total employment under asymmetric information to fall.

An example of the above situation occurs when $\lambda_1 = \lambda_2 = \lambda$, $\gamma_1 = 0$, $\gamma_2 = \lambda$. In this case shifts in wealth from the γ consumers to the λ consumers will raise the Walrasian level of $\overline{P}_x$ and lower the Walrasian level of $\overline{P}_y$. If we start out with a distribution of wealth such that $e_2 = 0$, then $P_x(e_1,0) = P_y(e_1,0)$. A redistribution of wealth would lower the asymmetric information level of employment if it kept the Walrasian level the same because it would create greater uncertainty among workers about their own firm's marginal value productivity of labor.[7/]

We see that changes in the distribution of wealth will cause relative price movements, which create uncertainty on the part of labor about its marginal value product. We have taken the convention that unequal final goods prices are associated with uncertainty about the marginal value product of labor within each industry. To see that this is just a convention, consider a world of perfect certainty. Free entry would lead resources to be allocated across industries in such a way that prices are determined by minimum average costs. Since firms have identical productions functions, minimum average cost would be the same. If we instead began with industries that had different cost functions, then the steady state - no shock situation would lead to final good prices which are unequal. However the profitability of labor would be equalized across industries. A shock which changed relative demands would, in the short run, create unequal profitability of hiring labor across industries. We assume that workers only know the distribution of profitabilities across industries and they think their firm's labor profitability is a random drawing from that distribution. Hence a shock which changes demand from its steady state value would cause uncertainty about labor productivity within each industry, which would cause a drop in employment relative to the Walrasian level.

We summarize the remarks following Proposition 2 with the following

Statement: Let the initial distribution of wealth have the property that final goods prices reveal to each worker the marginal value product of labor in his firm. Then consider any change in wealth across individuals which causes some industries to expand and others contract, but keeps the total Walrasian level of employment $\bar{\ell}$ constant. This change will cause a decrease in total employment $\ell(e_1, e_2)$ when there is asymmetric information.

5. Evidence and Conclusions

5a. Relative Price Variability As A Cause of Aggregate Output Variability

We have outlined a model of an economy subject to two kinds of shocks: (a) an observable shock to the relative demand for final goods which causes dispersion in relative prices, and (b) shocks, unobservable by workers , to the technology for transforming intermediate goods into final goods. Workers in the intermediate goods industry cannot observe the prices of the products they produce, but they can observe the cross sectional distribution of prices. That is, they know whether conditions are generally good or bad or dispersed, but not how their own particular industry is affected. A worker in a particular intermediate goods industry knows that the price of his output is determined by (1) a technological shock that determines which final goods industry uses his output intensively and (2) the price of the final good that uses his output intensively. When there is very little relative price dispersion among final goods, then it doesn't matter which final goods industry uses the worker's output. Thus the technological shock is of very little importance in creating uncertainty about the worker's marginal product when there is little dispersion of relative prices. Hence an increase in the dispersion of relative prices amplifies the effect of technological uncertainty on a worker's marginal value product.

We considered a model of optimal labor contracts in a situation where the workers have less information than the firm about their marginal value product. A relative price shock of the type described above increases the uncertainty which workers have about their marginal value product. We show that with an optimal asymmetric information employment contract the industries which are adversely affected by the relative price shock will contract more than they would under complete information (i.e., where workers could observe their marginal value product). On the other hand the industry which is favorably affected by the relative price shock will not expand by more than would be the case under complete information. Hence a relative demand shock, which would leave aggregate employment unchanged under complete information, will cause aggregate employment to fall under asymmetric information.

Before discussing potential sources for the relative price shocks, it is worthwhile to present some evidence that is consistent with relative price shocks having a causal role in the determination of aggregate output. Since our Propositions only compare the full information effect of relative demand shocks to the asymmetric information effect we have no direct conclusion as to whether an increase in relative price variability raises or lowers employment. However, if we assume that the shocks to relative demands have no effect under complete information, then our Proposition implies that aggregate employment will fall when relative demand variability rises. (To be more precise we showed that positive variability induces lower employment than no variability, but by continuity it follows that employment will fall when variability rises over a range near zero variability.)

Fischer [1982] contains a survey of the literature on relative price variability. He also studies the time series behavior of aggregate output, relative price variability and other macroeconomic variables. In a vector auto regression with relative price variability "put first," this variable can explain as much of the variability of output as interest rate, money or inflation innovations (see his Table 8), i.e. about 10% of the total variability of output. When relative price variability is "put after" interest rates, money and inflation, it does as well as inflation and money but worse than interest rates.

The relatively high explanatory power of relative price variability for output is of course consistent with models other than ours. For example all of Fischer's results are consistent with a Walrasian model where at time t, people get information that future output will fall and that the different components of output will fall in differing proportions. With a conventional money demand model this will imply that prices will rise in the future in differing proportions, and this in turn will raise prices today in differing proportions. Thus the future decrease in output will lead to an increase in expected inflation, and variability of inflation and high nominal interest rates, which is exactly what Fischer finds. Fischer also suggests three other models which are consistent with his observations.

(b) The Causes of Relative Price Variability

The model presented in Section 4 assumes that a change in the distribution of wealth is the source of a change in relative prices. There are clearly many sources of relative price variability other than changes in the distribution of wealth, e.g. variability in technology, tastes and the prices of imports and exports. We have focused on wealth redistributions as the source of relative price changes in order to provide the possibility of a comparison with existing macroeconomic models. In particular assume that the wealth redistribution occurs between nominal borrowers and lenders when there is an unanticipated movement in the price level. Though we did not present an intertemporal model with money and nominal prices, it would not be difficult to append an additively separable utility of real balances to preferences. Further we could model borrowing and lending associated either with life cycle effects or random shocks to income.[1/] In such a model with nominal borrowing and lending unanticipated inflation will have important effects on the distribution of wealth.

Approximately 50% of "wealth" is held in the form of nominally denominated debt.[2/] Imagine that the economy is composed of two types of individuals one of which is a nominal borrower and the other is a nominal lender. Then a 10% permanent drop in the price level will increase the real wealth of the lender by 50% of 10% = 5%. The reverse will happen to the nominal borrower. To the extent that the permanent drop of 10% in the price level is associated with expected deflation, then there will be a second effect in the wealth distribution in the same direction. Namely the real price of long term nominal debt will rise due to the fall in the nominal interest rate. People over 55 (the "old") tend to be nominal creditors while people under 55 (the "young") tend to be nominal debtors. Fischer and Modigliani (1978) estimate (to within an order of magnitude) that a 1%

unanticipated increase in the price level will transfer wealth with a flow value of about 1% of GNP.

Wealth redistributions will have no effect on relative prices if wealth is redistributed between groups that have the same homothetic preferences. However there is some evidence that there are systematic differences among individuals in their preferences by age. Michael (1979), p.41 used the Bureau of Labor Statistics' consumer expenditure survey to find that there are systematic and significant differences among individuals' consumption proportions by age. The classification of borrowers and lenders by age may not be the most useful for tracing the consequences of the wealth redistribution. We mention it here only because it is the only classification for which there is evidence that the individuals are jointly sorted by desired consumption proportions and debt positions.

There are some other obvious sources of wealth redistributions which may be of sufficient magnitude to have caused observed output fluctuations. For example unanticipated changes in nominal interest rates due either to real or nominal factors will redistribute wealth between long term borrowers and lenders, and this could be a source of relative price variability. Alternatively, a large decrease in the real value of assets such as houses and stocks can cause a large redistribution of wealth between the young and the old. Exogenous changes in the productivity of capital could be the cause of a change in the real value of assets.

(c) Relative Demand Shifts vs Aggregate Demand Shifts

The previous discussion may obscure some of the difference between our model and aggregate demand models of the cycle. To the extent that we think that changes in aggregate demand can cause a wealth redistribution which can cause employment fluctuations, there is some similarity between our model and aggregate demand models. One important difference however is that there is no presumption in our model that the sign of the aggregate demand shock matters. A large unanticipated inflation can cause the same increase in relative price dispersion as a large unanticipated deflation.[3/] Hence there is no presumption that unanticipated inflation is expansionary while unanticipated deflation is contractionary. To a first approximation (i.e., where the Walrasian equilibrium total output is independent of the wealth distribution), it would be the absolute value of the unanticipated price level change which would be negatively correlated with output in our model. Further, if relative price variability is an independent variable explaining output then unanticipated inflation should have little incremental explanatory power.

Fischer (1982) and Blejer and Leiderman (1980) use innovations in inflation and relative price variability as explanatory variables for output. Their results are suggestive for each variable having some independent explanatory power for output in the Post World War II United States.[4/]

Fischer (1982) Figure 3, and Sims (1980) Table 3, both find that in the Post World War II period positive price innovations precede a fall in output. Our conclusion from this is that in the Post World War II period, though the data are suggestive of an independent effect of price innovations, the sign is the reverse of what would have been predicted by the models of Sargent or Lucas, or Barro, (see Barro (1981) for a survey of models where unanticipated inflation causes an increase in output).

The period before World War II is likely to be favorable to the unanticipated inflation model. Sims (1980), Table 3, finds that negative price innovations precede falls in output in the period between World War I and World War II.) Unfortunately, we have not been able to find any evidence which has attempted to distingusih the relative price variability hypothesis from the unanticipated inflation hypothesis in that period. In the pre World War II period, large unanticipated deflation may well be a proxy for high variability of relative prices. This is consistent with Parks' (1978) finding in his Tables 2 and 6.

Thus it seems that further empirical research needs to be undertaken to distinguish the hypothesis that unanticipated falls in money (or prices) decrease output, from the hypothesis that monetary or price level shocks of any sign decrease output. In addition further theoretical research needs to be undertaken to develop models where the sign of the publically observed shock, as well as its size, affects output.

Footnotes to Section 1

1/ See Barro (1981) for a survey of the literature on unobserved money supply shocks, and Grossman-Weiss (1982) for a model with unobserved real productivity shocks.

Footnotes for Section 2

1/ It is sometimes convenient to state that a feasible wage contract is a function $w(s, n)$ such that it is optimal for the firm to truthfully reveal s, i.e., for all $s, \hat{s}, n$

$$s f(\ell(\hat{s},n)) - w(\hat{s},n) \geq \hat{s} f(\ell(s,n)) - w(s,n) .$$

This inequality is equivalent to (2) because it can be easily verified from the inequality that $w(s_1,n) = w(s_2,n)$ when $\ell(s_1,n) = \ell(s_2,n)$, i.e., $w(s,n)$ depends on s only through ℓ.

2/ The basic idea behind our result is that when s is not observed by the worker, $\ell^*(s)$ can be induced by the wage contract only if $\frac{\partial w}{\partial \ell}(\ell,n_b) = R$. But this implies that $w(\ell,n_b) = w(0,n_b) + \ell R$. That is, the workers net income $w - \ell R$ is constant for all s. The firm bears all the risk. As far as risk sharing goes, the firm and the worker would like to raise the firm's income in low s states in return for lowering it in high s states. When s is not observed this can be achieved by raising $\frac{\partial w}{\partial \ell}(\ell,n_b)$ above R. This implies, for some $s < \bar{s}$, that $\ell(s,n_b) < \ell^*(s)$. At $s = \bar{s}$ there must be efficient employment since it can be shown that $\ell(s,n_b)$ is increasing in s, and if $\ell(s,n_b) < \ell^*(\bar{s})$, then $\frac{\partial w}{\partial \ell}(\ell^*(\bar{s}),n_b)$ can be set equal to R, with no loss of incentive compatibility and higher utility for the firm without lower utility for the worker.

The above result was proved by us for the situation where there was a discrete number of possible values for ℓ. The continuous ℓ cases can be achieved by taking a limit of our previous result. Taking the limit does not lead to equality between $\ell(s,n_b)$ and $\ell^*(s)$, for the reason given above: The worker bears no risk, and the efficiency loss from lowering $\ell(s,n_b)$ just below $\ell^*(s)$ will always be smaller than the benefits from increased risk sharing (since at a productive optimum small changes in ℓ have only a second order effect on $sf(\ell)-R\ell$).

3/ This can be seen as follows. When $n = n_b$ and $m = 2$, we are in the situation studied by Azariadis (1982). Let $s_1 < s_2$, $\ell_1 \equiv \ell(s_1,n_b)$, $\ell_2 \equiv \ell(s_2,n_b)$ and $w_1 \equiv w(\ell_1,n_b)$, and $w_2 \equiv w(\ell_2,n_b)$. Azariadis shows that in an optimal contract the inequality in (2.8) will be binding at $s = s_2$ when the worker is (almost) risk neutral, i.e., $s_2 f(\ell_2) - w_2 = s_2 f(\ell_1) - w_1$. If the full information employment obtains in both states, then

$$(*) \qquad s_2[f(\ell_2^*) - f(\ell_1^*)] = w_2 - w_1 \quad .$$

Now consider the difference in the firm's profit across the two states $\pi_2 - \pi_1 = s_2 f(\ell_2^*) - w_2 - [s_1 f(\ell_1^*) - w_1]$ $> s_2(f(\ell_2^*) - f(\ell_1^*)) - (w_2 - w_1) = 0$ by $(*)$. The fact that

$\pi_2 > \pi_1$, means the firm is bearing risk. If the worker is risk neutral, then this cannot be optimal. Note that $\pi_2 - \pi_1$ can be reduced by raising $w_2 - w_1$. From (*) this can be achieved by lowering ℓ_1 below ℓ_1^*. It is always optimal to do so because $s_1 f'(\ell_1^*) = R$, so a reduction in ℓ_1 slightly below ℓ_1^* has no first order effect on net total output in state 1: $s_1 f(\ell_1) - R\ell_1)$. However the risk sharing benefits are of the first order in ℓ_1.

Footnotes for Section 3

1/ The inequality in eq. (3.7) depends on the assumption that the firm's manager is risk averse. If managers hold well diversified portfolio's, then a shock which increases the cross sectional dispersion of profitability will have no impact on the manager's wealth. Hence he will be risk neutral with respect to such shocks. However suppose that the manager is an agent for the owners of the firm. Then the owners will tie the manager's remuneration to the performance of his own company. An optimal incentive scheme between the owner and the manager will <u>not</u> permit the manager to diversify away the risk associated with his firm's performance since this will dilute the manager's incentive to maximize profit. See Hart (1982) for an implicit contract model between a firm and its workers in the presence of a moral hazard problem between managers and owners.

2/ In more general versions of Lucas' model the aggregate unemployment rate may not be a suffficient statistic for the economy wide shock. However it is essential to his model that the economy wide shock itself (e.g. the money supply) is not directly observable.

Footnotes for Section 4

1/ If there are no futures markets, and labor at time t is used to produce goods at time $t+1$, then it might appear that workers and firms could have different information about the value of employing labor at t. However, if the workers wage at date $t+1$ can be made conditional on the date $t+1$ spot prices that the firm learns at t, then it can be shown that employment under an optimal contract will be at the same level as if both the worker and firm observed the date $t+1$ spot price at date t.

2/ We want to model the idea that workers know general labor market conditions better than conditions in their own firm. Thus workers observe the cross sectional mean and variance of employment from newspaper reports on the economy wide and regional unemployment rates. They do not know the state of demand for their own firm's product. Further if there are many firms in a given industry, then the employment level of other identical firms will provide a useful signal to workers in a given firm. We assume that no such signal is available. To the extent that firms in the same industry are not completely identical but are subject to idiosyncratic shocks to demand, then the employment level of other firms in the same industry may be a poor signal about a given firm's demand.

3/ It is not difficult to show that, under our assumptions, the optimal contract is unique.

4/ We must also add the condition that $U(0) \leq \bar{U} \leq U^*$, where U^* is that level of utility at which firms are indifferent between signing a contract with a worker and not operating at all. It is clear that from this that there will in general be different equilibria according to where $\bar{U}$ lies in this range. This indeterminacy results from our assumption that there is an inelastic, integral supply of workers at date 0 and would disappear if we had a smooth upward sloping supply curve of date 0 workers. It should also be pointed out that, while in the model of this paper equilibrium prices and employment will in general depend on the value of $\bar{U}$, this is not the case if U and V exhibit constant absolute risk aversion. In this case the employment function $\ell(v,n)$ which solves (4.15)-(4.17) is independent of $\bar{U}$ (see Grossman and Hart [1982]).

5/ It can be shown that, under the usual assumptions, contract equilibrium under asymmetric information exists.

6/ Note that if a monetary contraction causes the change in the distribution of wealth, then prices of goods relative to the non produced good (money) will fall rather than rise. An implication of our result is that the decrease in supply which is associated with the increased uncertainty will cause prices in terms of money to fall by less than they would under complete information.

Footnotes (cont'd)

7/ Note that, in general, a simple transfer of wealth, i.e., where $\Delta e_1 = -\Delta e_2$ will not keep the Walrasian level of employment constant. In our simple example with two types of produced goods, there is a one dimensional locus of points (e_1, e_2) where $\ell(e_1, e_2) = \overline{\ell}$. There is no reason for that locus to coincide with the set of (e_1, e_2) such that $e_1 + e_2 =$ constant. In the case with m- produced commodities and at least 3 consumer types, the Walrasian total employment $\overline{\ell}$ will depend on all the E_i, $\overline{\ell}(E_1, E_2, \ldots, E_m)$. There will then be an m-1 dimensional locus of $(E_1, \ldots, E_m)$ points where $\overline{\ell}$ is constant. So it is easy to merely redistribute income across consumer types to keep Walrasian employment constant.

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