Risk Sharing, Indivisible Labor and Aggregate Fluctuations (Revised)

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and Aggregate Fluctuations

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Abstract

This paper compares the mechanisms through which indivisible labor and risk sharing can affect aggregate fluctuations in the labor market. Both of these features act to decrease curvature in preferences, but, whereas indivisible labor acts to alter preferences over leisure, risk sharing acts to alter preferences over consumption.

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Section 1: Introduction

The aggregate labor market has been a persistent problem for economists trying to build equilibrium models capable of reproducing aggregate economic time series. After the seminal work by Lucas and Rapping [7] there were many papers arguing that elasticities of labor supply were too low for equilibrium models to be consistent with observed magnitudes of fluctuations in total hours and wages (see Altonji and Ashenfelter [2], Altonji [1], and Ham [4], for example). Prescott [8] argues that competitive theory does not require that payment and delivery of goods be contemporaneous, and suggests that it is more instructive to look at hours and productivity instead of hours and wages. However, this did not change the nature of the problem to any appreciable extent. In another very important paper, Kydland and Prescott [6] find the total hours to productivity ratio to be the most serious problem in trying to represent post World War II time series with a real business cycle model. Hansen [5] imbedded the indivisible labor model of Rogerson [9] into a neoclassical growth model and showed that this feature caused a substantial improvement in the model's performance.

The lotteries used in Rogerson to overcome the indivisibility in labor are at first glance similar to those contracts used by Azairiadis [3] in discussing risk sharing. This paper considers these two features - risk sharing and indivisible labor, and analyzes the mechanisms by which these features operate in influencing aggregate fluctuations. The conclusion is that these methods operate via very similar but entirely distinct channels. Rogerson showed that indivisible labor makes the aggregate economy behave as if preferences were linear in leisure. It will be shown here that risk sharing makes the aggregate economy behave as if preferences were linear in consumption.

Section 2: Fluctuations in Hours and Productivity: A Parametric Example

This section considers a quadratic example which will prove useful in discussing the results obtained later in the paper. Imagine a one period deterministic economy where labor is used to produce output according to a linear technology with coefficient θ. There is one representative consumer with preferences over consumption and leisure defined by

$$u(c) - v(h)$$

where it is assumed that

$$u(c) = c - \frac{\alpha}{2}c^2$$

$$v(h) = h + \frac{\beta}{2}h^2$$

Of course these functions are only applicable over a limited range, but this will not matter for the discussion here. An optimal (and, hence, competitive equilibrium) allocation is found by solving:

$$\max_h \; u(\theta h) - v(h)$$

$$\text{s.t. } 0 \leq h \leq \bar{h}$$

where $\bar{h}$ is the time endowment. For the functions u(c) and v(h) defined above, the solution to the above problem is given by

$$h = \frac{\theta - 1}{\beta + \alpha\theta^2}$$

As mentioned in the introduction, it is of interest to study how h responds to changes in productivity θ, and, in particular, how this response is affected by the parameters of preferences.

This paper will be concerned with the properties of the u(c) function and thus the change in the elasticity of hours with respect to productivity caused by a change in α will be of interest. Straightforward substitution gives:

$$\frac{\partial}{\partial\alpha}\left(\frac{\partial h}{\partial\theta}\cdot\frac{\theta}{h}\right) = \frac{-2\theta^2\beta}{[\beta+\alpha\theta^2]^2} < 0.$$

Hence, decreases in α increase the response of hours to changes in productivity. This makes sense intuitively. Assuming that the labor supply schedule is upward sloping (at least locally) in productivity, then one of the factors which discourages an increase in labor supply is the declining marginal utility of consumption. Hence, additional increases in labor supply produces successively smaller increments in utility. Conversely, if productivity declines, one of the factors which prevents labor supply from decreasing is that the worker is giving up successively more utility as consumption decreases. Intuitively, therefore, the steeper the marginal utility of consumption curve, the less responsive labor supply will be. In the above model, changing α amounts to changing this steepness and hence the result is expected.

One could repeat the same type of argument with respect to the function $v(h)$. Again, there is some intuition suggesting that if $v'(h)$ is less steep then fluctuations in hours relative to productivity will be greater. The previously mentioned work by Rogerson and Hansen illustrated that the case of indivisible labor is equivalent to making $v(h)$ linear (hence $v'(h)$ is flat) and that this can produce greater fluctuations. In general, this effect depends upon the $u(c)$ function and how the income and substitution effects interact. Hansen demonstrated it for the case where $u(c)$ is logarithmic. It would not hold true if $u(c)$ were quadratic. In the example described above it can be shown that

$$\frac{\partial}{\partial\beta}\left[\frac{\partial h}{\partial\theta}\,\frac{\theta}{h}\right] > 0.$$

The rest of this paper is devoted to studying through what mechanism adding a risk neutral agent to a representative worker economy changes the nature of aggregate fluctuations.

Section 3: The Economies E and $\bar{E}_a$

The economy E lasts for a single period. There are three goods: labor, capital and output. Labor and capital are used to produce output according to a production function subject to a stochastic technological shock denoted by $f(K,H,s)$. In this expression K is capital, H is labor and s is the realization of the technology shock. It is assumed that there are N possible realizations of s, labelled $s_1,\ldots,s_N$ where π_i is the probability that s_i occurs. For each value of s it is assumed that $f(K,H,s)$ satisfies:

(i) twice continuously differentiable in K,H

(ii) homogeneous of degree one in (K,H)

(iii) weakly concave in (K,H), strictly concave in each of K and H separately.

(iv) strictly increasing in each of K and H, $f(0,0,s) = 0$

(v) $\lim_{K\to 0} f_1(K,H,s) = +\infty$, $\lim_{H\to 0} f_2(K,H,s) = +\infty$.

There are two types of agents in the economy. There is a single representative worker endowed with one unit of capital and one unit of time, any fraction of which can be supplied as labor. Capital is supplied inelastically. If a worker receives c units of consumption and supplies h units of labor they receive utility given by:

$$u(c) - v(h)$$

where it is assumed that

(i) $u(c)$, $v(h)$ are twice continuously differentiable

(ii) $u(c)$, $v(h)$ are strictly increasing

(iii) $u(c)$ is strictly concave, $v(h)$ is strictly convex

(iv) $\lim_{c \to 0} u'(c) = +\infty$, $\lim_{h \to 0} v'(h) = 0$, $\lim_{h \to 1} v'(h) = +\infty$

The other agent has no endowment of time or capital but is endowed with W units of output. It is assumed that $W > \max_{s_i} f(1,1,s_i)$. The importance of this assumption will become clear later on, but basically it means that in equilibrium when the second agent undertakes risk sharing with the workers there will be no danger of violating the non-negativity of consumption constraint for the second agent. If this endowment was small this problem could arise and prevent complete risk sharing from arising. The second agent has preferences defined over consumption and is assumed to be risk-neutral so that the utility received by consuming c units of output is simply c.

Both agents evaluate a state-contingent commodity bundle by computing the expected utility. The timing of the model is such that the state of nature (the technology shock) is revealed before any production or consumption activity takes place, so it will be possible for agents to enter into contracts contingent upon the realization of s.

Note that the economy E is very similar to that commonoly used in the early implicit contracts literature (e.g. Azariadis [3]). One implicit difference is that in those models it is usual for the risk-neutral agent to be endowed with the capital. The reason for the deviation from this situation is that the economy E is going to be compared to another economy $\bar{E}_a$ (to be described below) where the risk neutral agent does not exist. Since the analysis wants to focus on the effect of changing only this feature it is desireable to have the endowment of capital distributed in such a manner that it is not influenced by removing the risk neutral agent.

The economy $\bar{E}_a$ is identical to the economy E except in two respects. The first, as mentioned above is that the second agent does not exist. The second is that the preferences of the worker are now different, so that if a worker receives c units of consumption and supplies h units of labor the utility obtained is given by

$$ac - v(h)$$

where a is the subscript in $\bar{E}_a$ and v(h) is the same function as before. It is assumed that $a > 0$.

Section 4: Equilibria for E and $\bar{E}_a$.

This section characterizes the equilibrium allocations for the two economies E and $\bar{E}_a$ and proves a certain type of equivalence exists between the two. Prior to doing this, some notation is required. States of nature will be indexed by i. Prices for output, capital and labor respectively in state i will be p_i, q_i, and w_i. Consumption and labor supply of the worker in state i will be denoted c_i and h_i. Supply of capital will always be equal to one. The firm's demand for labor and capital in state i will be denoted by H_i and K_i. The consumption of the risk neutral agent in state i will be denoted by $\hat{c}_i$.

Finding equilibrium allocations for $\bar{E}_a$ is a straightforward exercise. Because $\bar{E}_a$ contains only one type of agent the equivalence between competitive allocations and Pareto optima implies the following.

<u>Proposition 1:</u> If (c_i, h_i, H_i, k_i, K_i, p_i, q_i, w_i, i=1,...,N) is an equilibrium for $\bar{E}_a$, then (c_i, h_i, i=1,...,N) is the unique solution to:

$$\text{(P-1)} \quad \underset{(c_i,h_i)}{\text{Max}} \sum_{i=1}^{N} \Pi_i (ac_i - v(h_i))$$

$$\text{s.t.} \quad 0 \leq c_i \leq f(1,h_i,s_i) \quad i = 1,\ldots,N$$

$$0 \leq h_i \leq 1 \quad i = 1,\ldots,N$$

<u>Proof:</u> Follows directly from the two welfare theorems (see e.g. Takayama [10].//

Finding equilibrium allocations for E is at least in principle more difficult. This follows from the fact that there are two different kinds of agents and hence one needs to know the correct weights to attach to their individual utilities in computing an optimal allocation. It will be shown that this does not present a major obstacle for economies like E. In particular, the following holds:

<u>Proposition 2:</u> If (c_i, h_i, $\hat{c}_i$, H_i, K_i, p_i, q_i, w_i, i=1,...,N) is an equilibrium for E then (c_i, h_i, i=1,...,N) is the unique solution to:

$$\text{(P-2)} \quad \underset{c_i h_i}{\text{Max}} \sum_{i=1}^{N} \Pi_i (u(c_i) - v(h_i))$$

$$\text{s.t.} \quad \sum_{i=1}^{N} \Pi_i c_i \leq \sum_{i=1}^{N} f(1,h_i,s_i) \quad i=1,\ldots,N$$

$$c_i \geq 0 \quad i = 1,\ldots,N$$

$$0 \leq h_i \leq 1 \quad i = 1,\ldots,N$$

<u>Proof:</u> See Appendix.

These two propositions can be used to prove the next result.

Proposition 3: If $(c_i, h_i, i=1,\ldots,N)$ is part of an equilibrium allocation for E then there exists an a such that $(\bar{c}_i, h_i, i=1,\ldots,N)$ is part of an equilibrium allocation for E_a.

Proof: The proof will follow directly from the first order conditions for problems (P-1) and (P-2). By the assumptions made on the functions involved it is clear that the solutions will be interior. From proposition two, if $(c_i, h_i, i=1,\ldots,N)$ is part of an equilibrium allocation then the following will hold:

$$(3.1) \quad c_1 = c_2 = \ldots = c_N = c$$

$$(3.2) \quad u'(c)f_2(1,h_i,s_i) = v'(h_i) \quad i = 1,\ldots,N$$

$$(3.3) \quad c = \sum_{i=1}^{N} \Pi_i f(1,h_i,s_i)$$

Now choose a to satisfy

$$a = u'(c)$$

From proposition one the equilibrium values of h_i for economy $\bar{E}_a$ must satisfy:

$$(3.4) \quad af_2(1, h_i, s_i) = v'(h_i) \quad i = 1,\ldots,N$$

Under the chosen value of a, this is simply equation (3.2) and hence the h_i's must be the same in the two equilibria. This proves the proposition.//

The significance of the above result is as follows. In both of the economies E and $\bar{E}_a$, capital is supplied inelastically. Hence, the profile of output, and hence, productivity, across states of nature is completely determined by the profile of h across states of nature. The above proposition says that if a is chosen appropriately the economies E and $\bar{E}_a$ have exactly the same prediction for movements in output, labor supply and productivity. In this sense an economy with risk sharing behaves in the aggregate like an economy in which all agents are risk neutral. This is perhaps not so surprising but it is interesting when viewed with the discussion from section two in mind. There it was commented that if one starts with a single agent economy, with preferences given by u(c) - v(h) that loosely speaking, decreasing curvature in both u(c) and v(h) increases the response of hours to changes in productivity. The work by Rogerson on indivisible labor demonstrated that making labor indivisible is equivalent at the aggregate level to making the function v(h) linear, thus increasing the magnitude of fluctuations in hours worked to productivity. Hansen has performed a calibration exercise similar to that of Kydland and Prescott and shown that this effect is potentially important empirically. The results obtained in this paper illustrate that adding a risk neutral agent into this type of an economy is equivalent at the aggregate level to making the function u(c) linear. Again, this will increase the magnitude of fluctuations in hours relative to those in productivity. What is interesting is that these two methods have such similar but distinct effects. One operates through changing the v(h) function whereas the other operates through changing the u(c) function. By the symmetry of the two effects it would also be expected that the risk sharing effect would also be potentially important empirically. This has apparently never been demonstrated in a rigorous fashion in a manner similar to Hansen's work on indivisible labor.

Another distinction between the two models in the behavior of consumption. In the risk sharing model consumption is constant across states of nature. In the indivisible labor model consumption is the same for employed and unemployed workers but it varies across states of nature. The risk associated with the employment lottery is completely diversifiable, whereas since all agents are alike the risk associated with technological shocks cannot be diversified. It is commonly argued that one of the important implications of allowing for risk-sharing is that observed wages may be interpreted as consisting of two parts -- one part reflecting marginal productivity, the other reflecting the net result of the risk sharing; assuming that the firm can be identified with the risk neutral agent. This can be mistakenly interpreted as implying that allowing for risk sharing keeps the equilibrium allocation unchanged but gives a different interpretation of wages. The reason this is incorrect whould be apparent from the preceding analysis. Adding a risk neutral agent alters the profile of labor supply across states of nature, and hence alters the equilibrium allocation. In particular, even without worrying about the interpretation of wages, this effect alone predicts an increased variability in hours relative to productivity.

Section 5: Extensions

The results stated thus far have all been derived in a static economy. It is natural to question to what extent they extend to dynamic economies. First note that the static context used here is appropriate for analyzing a dynamic economy in which there are no factors which cause the decisions in different time periods to be dependent. Several commonly used techniques to create this dependence would seem to not alter the nature of the results obtained at all. These are capital accumulation, a "fatigue" factor in labor supply (i.e. the individual does not like to work hard for two consecutive periods), and adjustment costs in labor for either the worker or firm. No formal result will be offered here but it should be clear that the same arguments used above will continue to hold. Another commonly used technique is to specify preferences over consumption such that the individual is penalized (in terms of utility) for changes in consumption over time.

This case is potentially more difficult but in practice is handled easily. Adjustment costs in consumption are simply another source of concavity. If agents have the same discount rate then the existence of a risk-neutral agent will simply cause consumption to be smoothed over time and over states of nature. Hence, in equilibrium marginal utility of consumption will be constant, and this is the key property.

Another extension which is relatively straightforward is to consider the case where there are, say M types of workers. It should be clear from the preceding arguments that it is possible to show that this economy would behave as if it were populated by M risk-neutral agents, although each would have a different coefficient of a on their utility functions.

Section 6: Conclusions

This paper contrasts the manners in which both indivisible labor and risk sharing act to influence aggregate fluctuations in the labor market, in particular the relative size of fluctuations in total hours and productivity. Whereas indivisible labor operates through making preferences appear to be linear in leisure, risk sharing makes it appear that preferences are linear in consumption. Although these mechanisms are very similar they are clearly distinct. Future work should compare the empirical importance of these two processes, perhaps using the methodology of Hansen.

Appendix

Proof of Proposition 2:

The proof proceeds in a series of lemmas.

Lemma 1: If $(c_i, h_i, \hat{c}_i, K_i, H_i)$ is an equilibrium allocation for E then it is Pareto optimal.

Proof: Follows directly from first welfare theorem.//

Lemma 2: If (p_i, q_i, w_i) are equilibrium prices for E then there exists $\lambda > 0$ such that $p_i = \lambda\pi_i$, $i = 1, \ldots, N$.

Proof: This follows from the fact that the second agent has linear indifference curves and that $W > \max_i f(1,1,s_i)$. Hence, if this condition is not met this agent's demand is inconsistent with the aggregrate resource constraint.//

Lemma 3: If $(c_i, h_i, \hat{c}_i, K_i, H_i)$ is an equilibrium allocation then $\sum_{i=1}^{N} \pi_i \hat{c}_i = W$.

Proof: The risk neutral agent solves the following problem:

$$\max_{\hat{c}_i} \sum_{i=1}^{N} p_i \hat{c}_i$$

$$\text{s.t.} \quad \lambda \sum_{i=1}^{N} \pi_i \hat{c}_i \leq \lambda W$$

$$\hat{c}_i \geq 0 \quad i = 1, \ldots, N$$

By monotonicity, the budget constraint will be binding. Hence $\sum_{i=1}^{N} \pi_i \hat{c}_i = W$.//

Lemma 3 claims that the risk neutral agent's utility in equilibrium will be equal to W. Hence, by lemma 1 an equilibrium will be the solution to

$$\text{(P-3)} \qquad \underset{c_i, h_i, \hat{c}_i}{\text{Max}} \quad \sum_{i=1}^{N} \pi_i (u(c_i) - v(h_i))$$

$$\text{s.t.} \quad c_i + \hat{c}_i \leq f(1, h_i, s_i) + W \quad i = 1, \ldots, N \qquad \text{(A-1)}$$

$$\Sigma\, \pi_i \hat{c}_i = W \qquad \text{(A-2)}$$

$$0 \leq h_i \leq 1 \quad i = 1, \ldots, N$$

$$c_i \geq 0, \ \hat{c}_i \geq 0 \quad i = 1, \ldots, N$$

The final step is to show that this problem gives the same solution for $(c_i, h_i, i=1, \ldots, N)$ as

$$\text{(P-4)} \qquad \underset{c_i, h_i}{\text{Max}} \quad \sum_{i=1}^{N} \pi_i (u(c_i) - v(h_i))$$

$$\text{s.t.} \quad \sum_{i=1}^{N} \pi_i c_i \leq \Sigma \pi_i f(1, h_i, s_i) \qquad \text{(A-3)}$$

$$0 \leq h_i \leq 1. \quad 0 = 1, \ldots, N$$

$$c_i \geq 0 \quad i = 1, \ldots, N$$

Note that (P-3) and (P-4) contain only $(c_i, h_i, i=1, \ldots, N)$ in the objective functions. Hence, if the constraint sets imply the same alternatives for these variables, problems (P-3) and (P-4) will imply the same choices for $(c_i, h_i, i=1, \ldots, N)$.

It is straightforward to show that if $(c_i, h_i, \hat{c}_i, i=1,\ldots,N)$ satisfy the constraints for problem (P-3) that $(c_i, h_i, i=1,\ldots,N)$ satisfy the constraints for problem (P-4). Multiply the i^{th} equation in (A-1) by π_i and sum over i to obtain:

$$\sum_{i=1}^{N} \pi_i c_i + \sum_{i=1}^{N} \pi_i \hat{c}_i \leq \sum_{i=1}^{N} \pi_i f(1,h_i,s_i) + W.$$

But by (A-2) $\sum_{i=1}^{N} \pi_i \hat{c}_i = W$, thus this expression reduces to (A-3).

Now the result needs to be proven in the other direction. Suppose $(c_i, h_i, i=1,\ldots,N)$ satisfies (A-3). Define

$$\hat{c}_i = W + f(1,h_i,s_i) - c_i, \quad i = 1,\ldots,N.$$

Then by definition:

$$c_i + \hat{c}_i = W + f(1,h_i,s_i), \quad i = 1,\ldots,N.$$

Also:

$$\sum_{i=1}^{N} \pi_i \hat{c}_i = \sum_{i=1}^{N} \pi_i W + \sum_{i=1}^{N} \pi_i (f(1,h_i,s_i) - c_i) = W \text{ by (A-3)}.$$

Hence (A-1) and (A-2) are satisfied. Finally, to show that $\hat{c}_i \geq 0$ observe that the solution to problem (P-2) will involve $c_i = c_j$ for all i,j. Hence it follows that

$$\begin{aligned} c_j &\leq \sum_{i=1}^{N} \pi_i f(1,h_i,s_i) \quad j = 1,\ldots,N \\ &\leq \sum_{i=1}^{N} \pi_i g(1,1,s_i) \\ &\leq W. \end{aligned}$$

This completes the proof.

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