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Can Market-Clearing Models Explain U.S. Labor Market Fluctuations?

Victor E. Li

Modern business cycle theories are evaluated on the basis of their ability to explain key empirical features of the post-war U.S. business cycle. The failure of nonmarket-clearing macro models to account for the rise of unemployment and inflation in the early 1970s led to the rise of New Classical explanations of the business cycle. In particular, the real business cycle (RBC) approach has received much attention in economics because it provides microeconomic foundations for macroeconomic behavior and emphasizes the importance of a quantitative evaluation of the theory's predictions. RBC theory shows how fluctuations in macroeconomic aggregates (recessions and booms) can result from the optimal response of businesses and households to real economic disturbances to technology. These theories are based upon the market-clearing assumption that prices rapidly adjust to demand and supply conditions. Kydland and Prescott (1982) and Long and Plosser (1983) demonstrated that such an approach could explain important facts regarding U.S. business cycles. Using a standard model of economic growth with empirically plausible shocks to aggregate productivity, or technology shocks, their artificial economies generated business cycles remarkably similar to the actual economy.

While successful at replicating some key business cycle features, one of the primary weaknesses of standard RBC models is their inability to account for some important aspects of U.S. labor market fluctuations. For example, the standard framework is unable to generate sufficient volatility of hours worked, relative to output and average labor productivity. It vastly overstates the contemporaneous correlation between hours and productivity, and it cannot account for the feature that labor productivity tends to lead hours worked over the business cycle. As a result, researchers in the past decade have focused on modifying the RBC framework to address these shortcomings.[1] One example pursued by Hansen (1985) is to treat labor supply as an indivisible decision (a decision to work or not to work), and hence, introduce equilibrium unemployment. Such an approach alters the individual trade-off between work and leisure over time, which makes labor supply more responsive to changes in the real-wage rate. Another direction is to incorporate additional shocks to the economy, such as changes in government spending (Christiano and Eichenbaum, 1992) or shocks to a home production technology (Benhabib, Rogerson and Wright, 1991). This not only makes labor supply more variable over time but lowers the correlation between hours worked and real wages. Finally, time lags between when a firm decides to hire labor or buy capital, and when those inputs become productive, could dampen the contemporaneous response of labor to a technology shock and, therefore, cause productivity to lead hours over the business cycle.[2]

This article will first summarize facts about U.S. business cycles and evaluate how a basic RBC model compares with these facts. Second, it will look at how a RBC model with indivisible labor supply is constructed and analyze its predictions for the labor market. Finally, it will develop a simple framework that demonstrates how a more realistic treatment of unemployment and incomplete risk sharing in an RBC

[1] See Hansen and Wright (1992) and Kydland (1995) for a survey of this literature.

[2] Merz (1995) introduces such time delays in the form of costly search in the labor market while Christiano and Todd (1996) considers a time-to-plan investment process.

Table 1

Relative Volatilities

	Expenditures			Labor Market		
	σ_Y	σ_C/σ_Y	σ_I/σ_Y	σ_H/σ_Y	σ_{PR}/σ_Y	σ_H/σ_{PR}
U.S. Data*	0.0179	0.51	3.14	0.79	0.46	1.72
RBC Model	0.0130	0.32	3.12	0.51	0.51	0.95
CRS Model	0.0173	0.30	3.21	0.76	0.29	2.63
ICRS-1 Model	0.0171	0.31	3.18	0.75	0.30	2.49
ICRS-2 Model	0.0157	0.36	3.10	0.73	0.38	1.90

Table 2

Dynamic Correlation of Output and Hours

	Corr(Y_t,H_{t+j})						
j =	-3	-2	-1	0	1	2	3
U.S. Data*	.30	.53	.76	.90	.88	.74	.58
RBC Model	.34	.51	.72	.98	.63	.35	.14
CRS Model	.33	.50	.72	.98	.62	.34	.14
ICRS-1 Model	.33	.50	.72	.98	.63	.35	.14
ICRS-2 Model	.31	.51	.74	.95	.88	.52	.24

*U.S. data uses chain-weighted logged and HP filtered quarterly time series, 1964:1 – 1994:4, constructed by Pakko (1997). Y = real GDP, C = consumption of nondurables and services, I = fixed nonresidential + consumer durables, H = total hours worked, PR = Y/H = average labor productivity.

model may provide an alternative approach to better account for these U.S. labor market facts. In particular, building upon the RBC model with indivisible labor, our framework looks at the situation where the risk of being unemployed cannot be completely shared across all individuals (unemployment insurance is incomplete).

U.S. BUSINESS CYCLES AND SOME LABOR MARKET FACTS

Figures 1-3 and the first rows of Tables 1-4 document some important U.S. business cycle properties based upon quarterly time-series data. The data are logged and detrended (using the Hodrick and Prescott filter, 1980) so that business cycles are measured as deviations of macro variables around this trend. Real GDP is denoted by *Y*, the expenditure aggregates are consumption (*C*) and gross private domestic investment (*I*), and the labor market variables are total hours worked (*H*) and average labor productivity ($PR \equiv Y/H$). Table 1 summarizes the relative volatility of these aggregates and shows the well-known fact that while consumption is about half as volatile as income ($\sigma_C/\sigma_Y = 0.51$), total business and residential investment fluctuates about three times as much as income ($\sigma_I/\sigma_Y = 3.14$). In terms of the labor market, Table 1 indicates that hours fluctuate almost as much as output ($\sigma_H/\sigma_Y = 0.79$), labor productivity is about half as volatile ($\sigma_{PR}/\sigma_Y = 0.46$), and hours fluctuate more than one and a half times as much as productivity ($\sigma_H/\sigma_{PR} = 1.72$).

Table 3

Dynamic Correlation of Output and Productivity

	$Corr(Y_t,PR_{t+j})$						
j=	-3	-2	-1	0	1	2	3
U.S. Data*	.43	.51	.56	.61	.37	.19	.01
RBC Model	.17	.38	.64	.98	.74	.54	.37
CRS Model	.01	.23	.51	.87	.75	.64	.52
ICRS-1 Model	.03	.24	.52	.88	.75	.63	.51
ICRS-2 Model	.18	.41	.72	.81	.46	.40	.32

Table 4

Dynamic Correlation of Hours and Productivity

	$Corr(H_t,PR_{t+j})$						
j =	-3	-2	-1	0	1	2	3
U.S. Data*	.47	.45	.37	.22	.13	.01	-.10
RBC Model	.03	.24	.54	.93	.73	.56	.41
CRS Model	-.14	.06	.36	.76	.68	.60	.52
ICRS-1 Model	-.13	.08	.38	.78	.69	.60	.51
ICRS-2 Model	.11	.39	.77	.59	.41	.37	.31

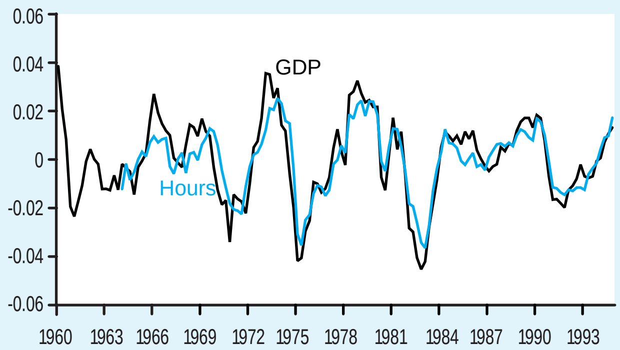
The first rows of Tables 2-4 contain the dynamic correlation of our selected labor market variables with three-quarter lags and leads. It highlights four important features. First, Figure 1 and Table 2 show that total hours are highly procyclical [$Corr(Y_t,H_t) = 0.90$]. Additionally, Table 3 indicates that it is more procyclical than productivity [$Corr(Y_t,PR_t) = 0.61$]. Second, Table 3 shows that while the correlation between output and productivity peaks contemporaneously, it is very close to the one-and two-period lagged correlations. Along with Figure 2, this suggests that productivity may lead the cycle weakly.[3] Third, the contemporaneous correlation between hours and labor productivity is small [$Corr(H_t,PR_t) = 0.22$]. Fourth, Table 4 and Figure 3 show very clearly that productivity leads hours over the cycle [$Corr(H_t,PR_t) < Corr(H_t,PR_{t-1}) < Corr(H_t,PR_{t-2})$]. These four features suggest that labor productivity is an important indicator of future economic activity.

These U.S. summary statistics given by the first rows of Tables 1-4 will be the benchmark with which we evaluate the performance of market-clearing RBC models. In particular, the article will first evaluate how the basic RBC model, given by the second rows of the tables, compares to these U.S. labor market facts. Next, we analyze the indivisible labor model with complete risk-sharing (CRS) and summarize these results in rows three of Tables 1-4. Finally, the paper builds upon this CRS model of indivisible labor by considering the more general case of incomplete risk sharing (IRS) between employed and unemployed individuals. Summary statistics for two versions of the IRS model are presented in the fourth and fifth rows of the tables.

[3] Others, e.g., Kydland (1995), using the establishment survey of hours worked, have found this leading role of productivity over the cycle to be more prominent than that indicated by this table.

Figure 1

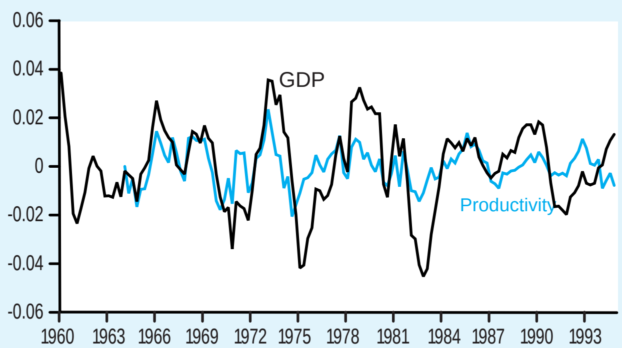
Real GDP and Hours*
H-P Deviations from the Trend



* Output is 1960:1-1994:
Hours is 1964:1-1994:4

Figure 2

Real GDP and Productivity*
H-P Deviations from the Trend



* Output is 1960:1-1994:4
Productivity is 1964:1-1994:4

A BASIC RBC MODEL AND THE FACTS

In a prototypical RBC framework, households behave as if they live forever. They care about current and expected-future consumption as well as current and expected-future leisure. The typical form of preferences adopted in the literature is a time-separable utility function where individuals discount the future:

$$(1) \quad u(c_0,l_0)+\beta u(c_1,l_1)+\beta^2 u(c_2,l_2) + \ldots = \sum_{t=0}^{\infty} \beta^t u(c_t,l_t),$$

where c_t and l_t are consumption and leisure, respectively, at date t, utility is increasing in c and l but also exhibiting diminishing marginal utility and $\beta < 1$ is the time discount factor.

Households earn income at each date by working $h_t = 1-l_t$ units at a wage rate w_t and renting capital k_t to firms at a rental rate r_t. At each date they spend their income buying goods for consumption and investment, I_t. This leads to the following flow-budget constraint that equates income to expenditures at date t:

$$(2) \quad w_t h_t + r_t k_t = c_t + I_t.$$

Gross investment is defined as new capital goods available at date t+1 less the undepreciated existing capital stock:

$$(3) \quad I_t = k_{t+1} - (1-\delta)k_t,$$

where $\delta < 1$ is the capital depreciation rate. Households maximize expected lifetime utility in equation 1 by choosing c_t, I_t, and l_t, subject to the budget constraint given by equation 2, and taking as given the market wage and capital rental rates.

Firms in this economy demand labor, h_t^d, and capital, k_t^d, to produce output y_t using a Cobb-Douglas production technology given by

$$(4) \quad y_t = A_t F(k_t^d, h_t^d) = A_t k_t^{\alpha} h_t^{1-\alpha},$$

where output is increasing in capital and labor inputs and exhibits diminishing marginal returns in each, and A_t is a productivity shock to this technology. The random process for these productivity shocks is given by $A_t = exp(z_t)$ where $z_{t+1} = \rho z_t + \varepsilon_{t+1}$, ε_t is a serially uncorrelated disturbance with zero mean and constant variance σ_ε^2 and $\rho < 1$ measures the degree of persistence of the shock.

Capital that is accumulated in the

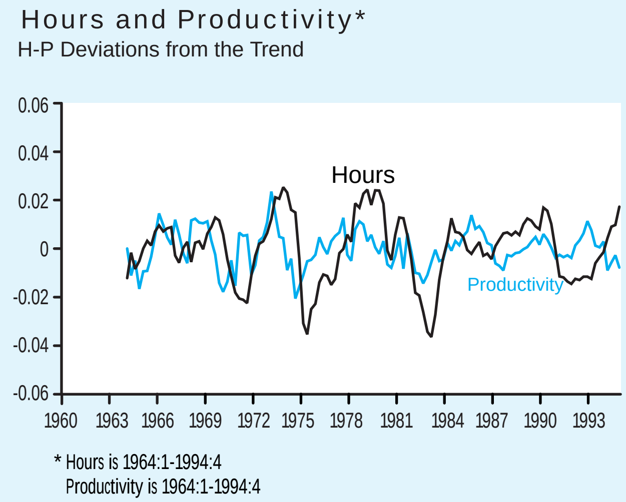
current period is not productive until the following period. Firms maximize profits and will demand labor and capital goods until the wage rate is equated to the marginal product of labor and the rental rate is equated to the marginal product of capital. The assumption of market-clearing ensures that factor prices will adjust to equate the demand and supply of labor, capital, and goods (i.e., $h_t = h_t^d$, $k_t = k_t^d$, and $y_t = c_t + I_t$).

A temporary unanticipated positive shock to A_t creates substitution effects on household behavior along two dimensions. First, the increase in the marginal product of capital provides an incentive to increase investment and intertemporally substitutes current for future consumption. Secondly, the productivity shock raises the marginal product of labor. Households respond to this by substituting leisure for current and future consumption. The overall impact will be a higher equilibrium rental rate, real wage, greater consumption, investment, work effort, and output during the period of the shock. Productivity disturbances are sometimes called the impulse to the business cycle, while the investment process is the mechanism that propagates these shocks over time.[4]

The model is then calibrated by solving it numerically, assigning parameter values, and simulating it over time (under the assumption that individuals have rational expectations regarding future economic variables).[5] Productivity shocks to technology are assumed to be temporary, but also persistent. The outcome is an artificial time series of economic aggregates that can be compared to the facts about U.S. business fluctuations.[6]

The second rows of Tables 1-4 give the predictions of the standard RBC model that can be directly compared to the data displayed in the first rows. Several predictions of the model do quite well. First, the volatility of consumption is significantly less than that of output while investment is substantially more volatile than output. Intuitively, because individuals are forward looking, they desire to spread consumption over time as dictated by the permanent income

Figure 3



hypothesis. Secondly, Table 2 shows that hours are strongly procyclical (even a bit more than the data indicate).

It also is clear from these tables that the major difficulties of the model rest in the labor market. First, the model cannot explain why hours are so volatile (σ_H/σ_Y is 0.51 in the model and 0.79 in the data). Second, the model overstates the procyclical nature of average labor productivity ($Corr(Y_t,PR_t)$ is 0.98 in the model and 0.61 in the data) and says that productivity is strongly contemporaneous with output while the data say that it is only weakly contemporaneous. Third, hours are more volatile than productivity in the data but less volatile in the model (σ_H/σ_{PR} = 0.95 in the model and 1.72 in the data). Fourth, the model vastly overstates the correlation between current hours and productivity (0.93 in the model and 0.22 in the data) and it is unable to explain why productivity leads hours over the cycle (the data show hours to be the most correlated with three-quarters lagged productivity).

Why does the standard RBC model have so much trouble explaining these labor market facts? The answer lies in Figure 4. Productivity shocks, which alter the marginal product of capital, can be viewed as shifts in labor demand along an upward sloping labor supply curve. In particular,

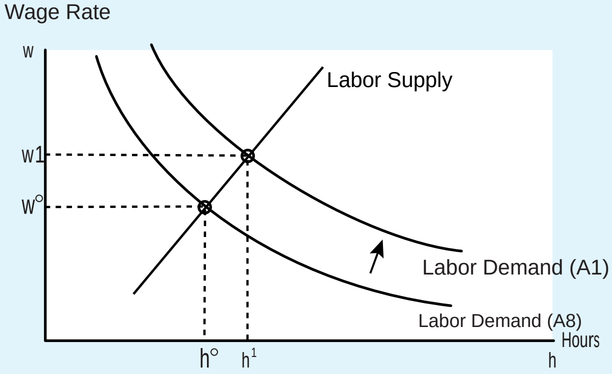
[4] It has been argued, however, that this propagation mechanism is weak because persistence in the technology shock itself is essential to generate a realistic amount of persistence in real output growth.

[5] We use log utility and parameters that are standard to the literature: $u(c,1-h) = ln(c) + Aln(1-h)$, $A = 2$, $\alpha = 0.36$, $\beta = 0.99$, $\delta = 0.025$, $\rho = 0.95$, and $\sigma_\varepsilon = 0.00721$.

[6] For more information, readers are directed to a detailed description of the process of solving, calibrating, and simulating RBC models contained in an article for this *Review* by Ritter (1995).

Figure 4

The Labor Market in a RBC Model
($A^{\circ} < A^{1}$)



using model parameters values based upon actual empirical evidence leads to a small intertemporal elasticity of substitution between consumption and leisure, and hence, a small labor supply elasticity (i.e., the labor supply curve is rather steep).[7] As a result, we see:

- Equilibrium hours will not be very responsive.
- Real wages, and hence marginal and average labor productivity, will change by more than hours.
- Technology shocks, which shift labor demand along labor supply, cause real wages and productivity to be almost perfectly correlated *and* contemporaneous with changes in output.

INDIVISIBLE LABOR IN A RBC MODEL

An important innovation to the real business cycle literature—aimed at resolving some of the inconsistencies between the basic model and the data—is to assume that labor supply is *indivisible* so that individuals are either working or not working, i.e., employed or unemployed.[8] In particular, individuals each face a random chance of being unemployed. The model assumes that firms offer labor contracts that are traded competitively. These contracts provide for unemployment insurance by specifying a guaranteed income flow to each individual worker, regardless of whether that worker is employed or unemployed. This income agreed upon by workers and firms, however, is contingent upon the probability, chosen by the worker, of being employed or unemployed in the current period. Such an environment will be equivalent to one where individuals insure each other against the random outcome of being unemployed; that is, the market for unemployment insurance provides a means to attain *risk sharing*.[9]

Hansen (1985) formalizes such an approach by considering the case where all individuals are identical in terms of skills and productivity, but each faces a random chance in each period of being employed with probability n_t and working L hours or unemployed with probability $1-n_t$, and working zero hours (i.e., there is an employment lottery). At the beginning of each period, individuals choose n_t to maximize the average of utility they receive if they should be employed or unemployed, weighted by their respective probabilities:

$$(5)\quad \sum_{t=0}^{\infty} \beta^t \left\{ n_t u(c_{1t}, 1-L) + (1-n_t) u(c_{2t}, 1) \right\},$$

where c_{1t} and c_{2t} are the individual's consumption choices contingent upon the realization of working and not working, respectively.

Risk sharing is captured by a budget constraint that equates an individual's expected income flow to his expected expenditures in the current

$$(6)\quad w_t n_t L + (1-n_t)(0) + r_t k_t = n_t c_{1t} + (1-n_t) c_{2t} + I_t.$$

The left-hand side of equation 6 is the sum of expected labor income over individual employment status and household rental income; the right-hand side is expected

[7] The labor-supply elasticity required for the model to generate sufficient hours to output volatility is close to two while empirical estimates suggest it is significantly less than one.

[8] This approach addresses the observation that about two-thirds of variations in hours worked come from individuals moving into and out of unemployment with only one-third from variations in hours when employed.

[9] Introducing an all-or-nothing employment decision will imply that the competitive structure of the economy may not correspond with a Pareto efficient equilibrium, i.e., an allocation where no one can be made better off without others being made worse off. Technically, allowing individuals to choose the probability of unemployment, and having a lottery to determine who will actually be unemployed is necessary to circumvent the problem of *non-convexities* in the labor-supply decision. (For more details the reader is directed to Hansen [1985], pp 315-16.)

expenditures on consumption over the employment lottery and household investment.[10] To maximize utility, subject to the budget constraint, individuals simply choose employment probability n_t, consumption plans c_{1t} and c_{2t} (which are contingent upon the outcome of the employment lottery), and investment. Firms in this economy own production technology in equation 4 and demand labor and capital in exactly the same manner as in the basic model. Since each representative firm employs many workers, aggregate labor supply is given by $n_t L$ hours and a labor market equilibrium occurs when $n_t L = h_t^d$.

This formulation of the model embodies the idea of complete risk-sharing (CRS). If it is costless to set up the insurance market for unemployment, and utility is separable in consumption and leisure, then the most beneficial arrangement is to provide for complete unemployment insurance. Such a situation entails that individuals receive the same income and consume identical amounts regardless of their employment status. Since this (costless) pooling of incomes implies that individuals would like to insure each other perfectly against unemployment and each is equally likely to be unemployed, the consumptions of employed and unemployed individuals are equalized, i.e., $c_{1t} = c_{2t}$ for all t.

Figures 5-7 show the impulse response plots of how selected variables in this CRS model respond to a one-period, one-standard deviation positive shock to A_t which persists over several quarters. The shock occurs in period 10 and the vertical axes of Figures 5-7 measure the percent deviation from steady-state values. All variables eventually converge back to their corresponding steady-state values following the one-time shock. Figure 5 indicates that the technology shock raises both employed and unemployed consumption by the same amount above their respective long-run values. Figure 6 shows a boom in investment expenditures in the period of the shock. As Figure 7 indicates, the responses of both output and hours worked are greatest in the period of the shock, while the surge in productivity gradually falls back to steady state. Thus,

Figure 5

Consumption of Employed and Unemployed-CRS Are Identical

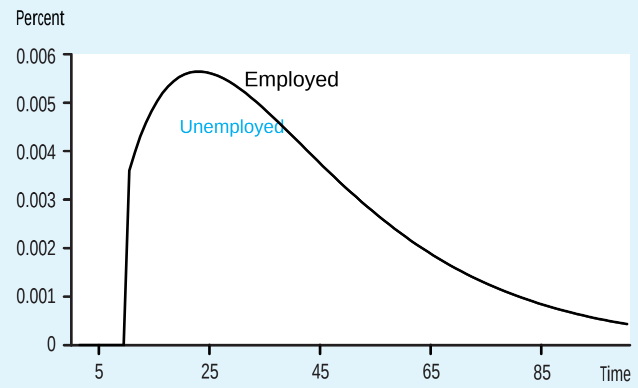
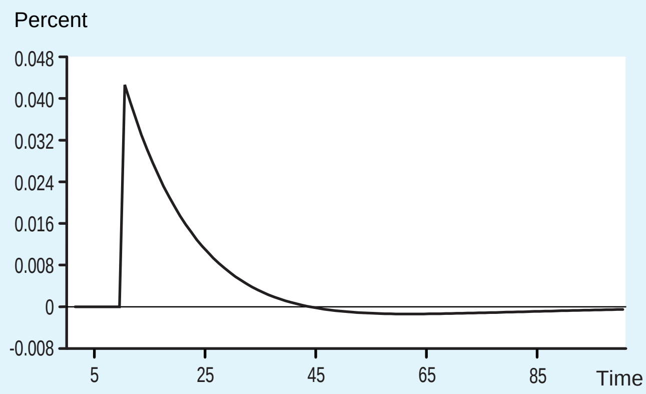


Figure 6

Investment-CRS



productivity certainly does not lead output over the business cycle and its correlation with hours worked is strongly positive.

These cyclical properties are quantified in the third rows of Tables 1-4.[11] As Table 1 shows, $\sigma_H/\sigma_Y = 0.76$. This means that the model does succeed in increasing the volatility of hours worked to a level very close to the data. It also explains why hours fluctuates more than productivity. In fact, the statistic $\sigma_H/\sigma_{PR} = 2.63$ is now too high, rather than too low, relative to the data. Intuitively, because an individual's labor supply is all or nothing at all, the aggregate labor supply elasticity can be much larger than the elasticity at the indi-

[10] Since there are a large number of households, the budget constraint (equation 6) also says that aggregate income must be equal to aggregate expenditures (i.e., it also corresponds to an aggregate resource constraint).

[11] To be comparable to Hansen (1985), we use $L = 0.53$; otherwise, the utility and production function as well as parameter values are identical to that in the standard model above.

Figure 7

Output, Hours, and Productivity

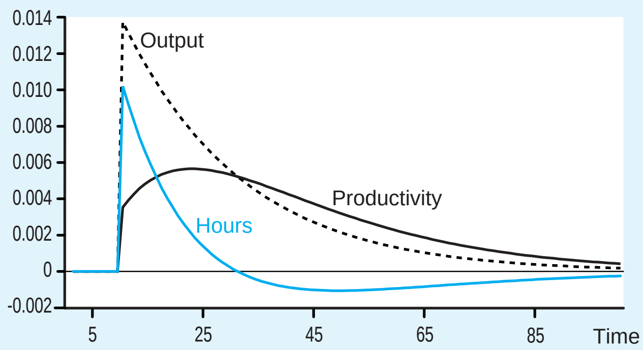
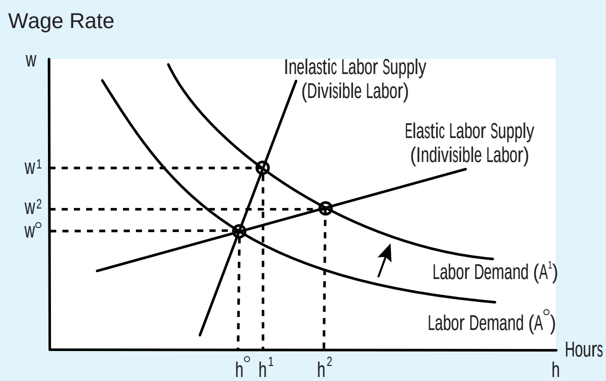


Figure 8

Labor Market (CRS)
($A^{\circ} < A^{1}$)



vidual level.[12] Figure 8 illustrates these labor market effects of a shock to technology with a larger aggregate labor supply elasticity. Finally, Table 4 indicates that although the correlation between hours and productivity is somewhat lower in this model than in the standard RBC model ($Corr(H_t, PR_t)$ = 0.76), it is still significantly larger than the correlation in the U.S. data. The strongest correlation between these two series is contemporaneous, rather than one in which productivity leads hours.

In the following section, we will build upon the RBC model with indivisible labor. In particular, we will suggest how a more realistic treatment of the income constraints that unemployed individuals face—and the notion of incomplete risk sharing—can help with the model's labor market predictions.

UNEMPLOYMENT AND INCOMPLETE RISK SHARING

In the indivisible labor model with complete risk sharing, individuals insure each other perfectly against variations in income due to unemployment. Such a frictionless market, however, also rules out potentially important liquidity constraints that unemployed individuals may face, and hence distorts how labor-supply decisions respond to aggregate shocks. This section provides an example of how incomplete risk sharing may improve upon the model's labor market predictions by considering the more natural case where the unemployed do not have direct access to current labor income.

In our example, the unemployment insurance market of the typical indivisible labor model is replaced with a simple one-period loan market, which permits borrowing and lending between individuals. The major source of friction in this loan market is that individuals make deposits, d_t, *before* the uncertainty about the state of the economy, i.e., the technology shock, A_t, is resolved. For example, there may be broker's fees, shoe leather, or other fixed costs of continuously adjusting these deposits once the initial decision is made.[13] Also, there is a resource cost of participating in this loan market, *s*, which is proportional to the size of d_t. This is meant to capture an implicit opportunity cost of making deposits relative to an outside alternative. This cost is rebated as a lump-sum transfer to households (which own the intermediaries) at the end of the period. Finally, individuals face a competitive market interest rate, R_t, on both deposits and loans.

Once the state of the economy is realized, individuals choose an employment probability. Then an employment lottery randomly assigns individuals to be employed or unemployed. While all individuals

[12] This partially addresses the criticism that RBC models require a large individual labor supply elasticity, but the required elasticity is still above one. Kydland and Prescott (1991) consider the case where individuals can vary both employment choice and hours worked. With fluctuations in hours coming from both margins, they arrive at a much more plausible figure for the relative volatility of hours to productivity.

[13] See Lucas (1990) and Fuerst (1992).

have equal access to rental income, unemployed individuals do not work and have no direct access to labor income. They are constrained to consume from their rental income and funds borrowed from the loan market, b_{2t}. Employed individuals, on the other hand, can consume and purchase capital goods from their rental and labor income as well as any additional funds they decide to borrow from the financial market, denoted as b_{1t}. We can write the unemployment consumption constraint as

$$(7) \qquad c_{2t} \le r_t k_t - d_t + b_{2t},$$

which takes into account that the income that individuals have available is net of their initial deposit decision. In place of equation 6, the average or aggregate budget constraint that allows individuals to pool their resources together, and hence share risk, is now given by

$$(8) \qquad n_t c_{1t} + (1 - n_t) c_{2t} + I_t + R_t \times \left[n_t b_{1t} + (1 - n_t) b_{2t} \right] + sd_t = w_t n_t L + r_t k_t + R_t d_t + \Pi_t.$$

The left-hand side of equation 8 is total expenditures by employed and unemployed individuals on consumption, interest payments on loans, household investment, and the implicit costs of participating in the loan market. The right-hand side is total income from wages earned by the employed, household rental income, interest on deposits, and lump-sum transfers of the financial market profits, $\Pi_t = sd_t$.[14] Since interest is paid on these loans at the end of the period, and no assets or IOUs are traded across periods, this is an intratemporal rather than intertemporal loan market. It simply permits individuals to smooth consumption against realizations of their employment status. Thus, while risk sharing guarantees that individuals are identical at the beginning of every period, or *ex ante*, an unanticipated aggregate shock causes their consumption decisions to differ based upon the random realization of their employment status, and hence they may not be identical *ex post*.

Figure 9

Deposits-CRS

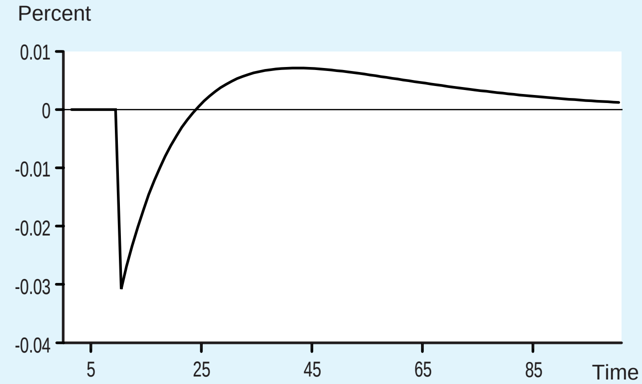
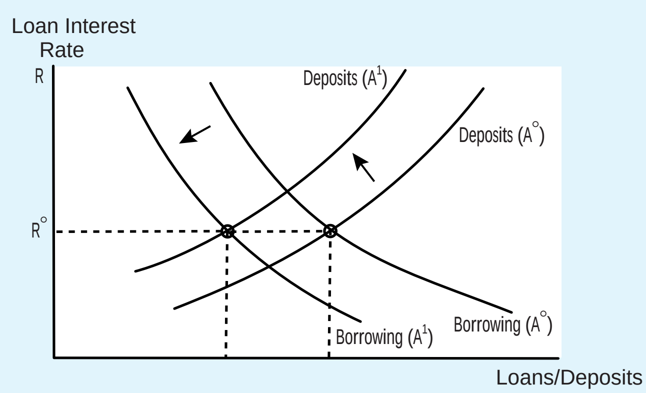


Figure 10

Loan Market Equilibrium in ICRS-1 Model $(A^\circ < A^1)$



Individuals take wages, rental rate, and loan market rates as given. They choose deposits (before the technology shock), an employment probability, consumption contingent on the realization of employment, and investment to maximize lifetime utility (equation 5), subject to budget constraints given in equations 7 and 8. Firms in this economy own the production technology (equation 4) and demand labor and capital in exactly the same manner as in the previous section. As in the CRS model, labor market equilibrium occurs when $n_t L = h_t^d$. There is an additional market-clearing condition

[14] In an economy with many identical intermediaries, households take these profits as a lump-sum quantity when they make their decisions. That is, Π_t is taken as given when households choose deposit, consumption, and labor supply decisions and $sd_t = \Pi_t$ holds *ex post*.

Figure 11

Consumption of Employed and Unemployed - ICRS-2

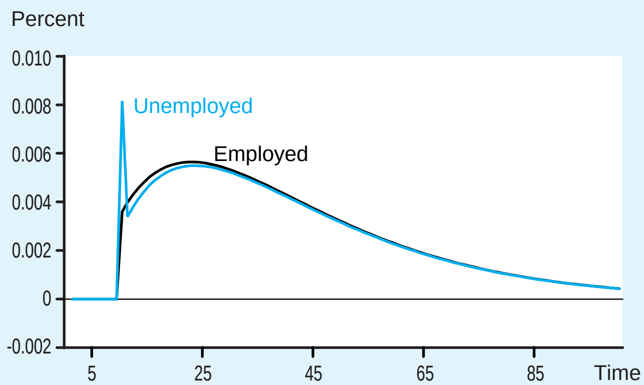


Figure 12

Investment - ICRS-2

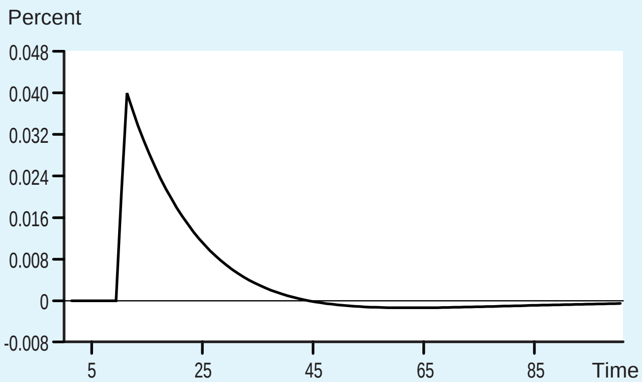
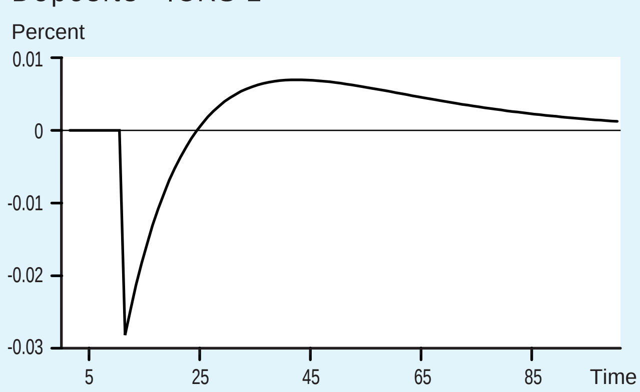


Figure 13

Deposits - ICRS-2



for the loan market that equates total financial market deposits to loans, and is given by $d_t = n_t b_{1t} + (1-n_t)b_{2t}$. In equilibrium, as long as $R_t > 0$, it will never be optimal for employed individuals to borrow in order to finance their consumption so that $b_{1t} = 0$. We will now summarize the major results of this set up, leaving the technical aspects of solving the model to the appendix.

First, consider the situation where there is no uncertainty about the aggregate state of productivity when the deposit decision is made (d_t is chosen after A_t is known), and there are no loan market participation costs ($s = 0$). This is the special case where risk sharing is complete both across and within periods so that $c_{1t} = c_{2t}$ for all dates t, and the model is identical to the CRS model of Hansen (1985) considered above. The loan market simply is acting as a transfer mechanism between employed and unemployed individuals and hence provides complete insurance against aggregate shocks to production and income. Figure 9 gives the impulse response plot of deposits to a positive shock to technology. Since the shock lowers unemployment, and there is no uncertainty about the shock when deposit decisions are made, supply and demand for these loans fall in equal amounts while the loan market interest rate remains constant (see Figure 10).

Next, consider the case where there are small but positive costs for participating in this loan market ($s > 0$), but still no uncertainty about the economy when deposits are made. In this case, the consumption of unemployed individuals now is lower than that of the employed, $c_{2t} < c_{1t}$, because it is costly for the loan market to transfer income across individuals. We call this form of incomplete risk sharing the ICRS-1 model. The impulse response plots are practically identical to those contained in Figures 5-7 (and omitted). The fourth rows of Tables 1-4 show that the cyclical properties of ICRS-1 indeed are very similar to the CRS model. Intuitively, as the state of the economy is observed when borrowing and lending decisions are made, risk is still shared efficiently (but not completely) across individuals and the costs of participating in the loan market make little difference to the dynamic effects of technology shocks. Hence, the labor market effects of ICRS-1 also can be illustrated by Figure 8.

Finally, we consider the form of incomplete risk sharing where there is uncertainty about the aggregate state of the economy when deposit decisions are made (d_t chosen *before* A_t is realized). Impulse responses to a one standard deviation positive-technology shock for this ICRS-2 model are shown in Figures 11-15. While the consumption of both employed and unemployed increases in Figure 11, unemployed consumption deviates from its long-run value by a greater percentage during the period of the shock. The reasoning is that loan market equilibrium requires $d_t = b_{2t}(l - n)$. Intuitively, since the supply of loanable funds, d_t, is fixed and cannot react in the period of the shock, the reduction of unemployment ($1-n_t$) reduces the total demand for loans by the unemployed and the loan market interest rate (Figures 14 and 16). Thus, the cost of financing consumption loans for each unemployed individual decreases and borrowing per unemployed individual, b_{2t}, rises. This has the effect of dampening the initial increase in hours and investment, as shown in Figures 12 and 15. As a result, productivity surges in the period of the shock while investment, hours, and output continue to rise during the period following the shock. Interestingly, the fact that output rises for two periods after the shock suggests that incomplete risk sharing strengthens a propagation mechanism, which is inherently weak in a standard RBC framework.

These features are captured more precisely in the model's summary statistics in the fifth rows of Tables 1-4. Table 1 indicates that the relative volatilities of each variable to output change very little when compared to the complete risk sharing case; however, the volatility of hours to productivity is now much lower (1.90 rather than 2.63 in CRS) and closer to the data. The dynamic correlations are now able to replicate several important features suggested by the impulse response diagrams. First, Table 4 shows that productivity leads

Figure 14

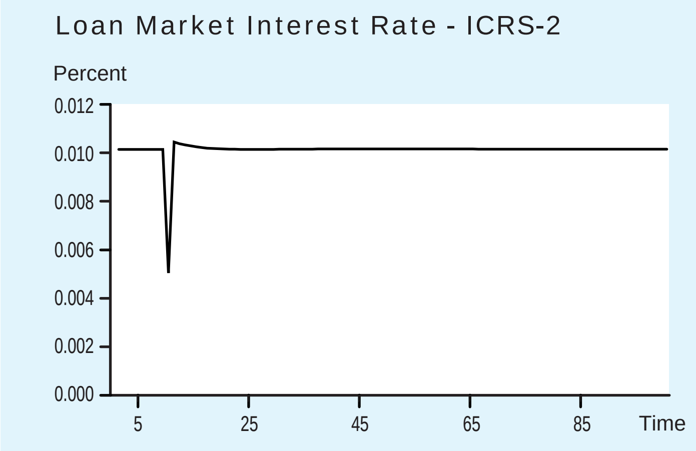
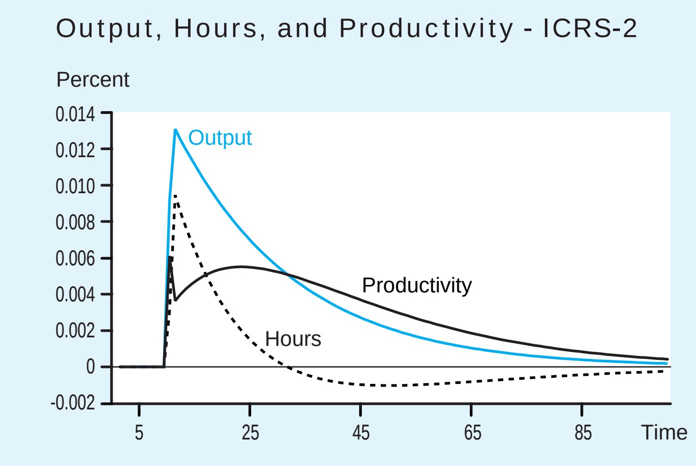


Figure 15

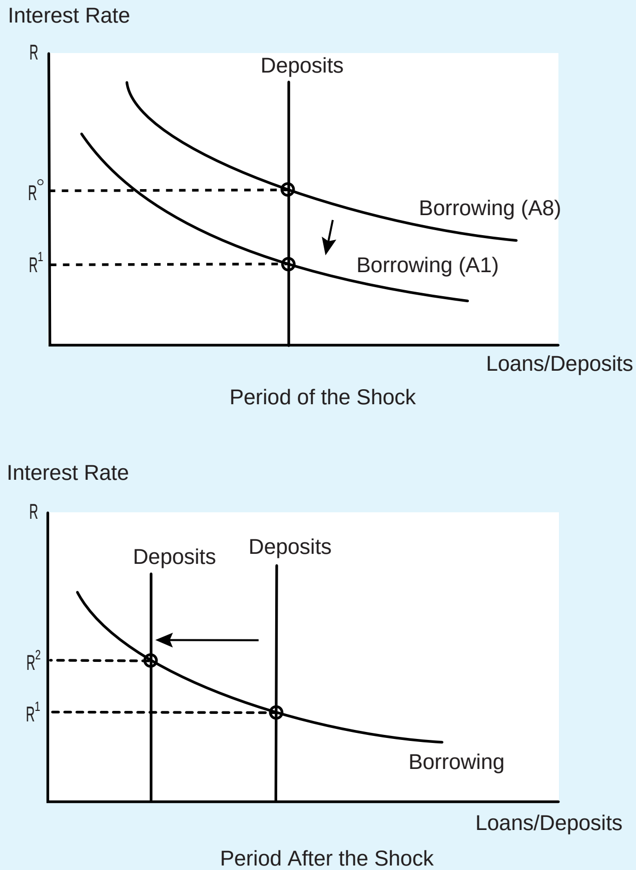


hours with the peak correlation occurring between current hours and one period lagged productivity. Secondly, Table 4 also indicates that the contemporaneous correlation between hours and productivity of 0.59 is significantly lower than that in the CRS model. Third, the contemporaneous correlation between output and productivity in Table 3 is lowered and the output-one period lagged productivity correlation is much stronger and closer to its contemporaneous correlation.

Again, some intuition behind these labor-market predictions can be obtained from a labor-market equilibrium diagram (Figure 17). Consider a *negative* unanticipated shock to technology. Given the inability of aggregate deposits to adjust to this

Figure 16

Loan Market Equilibrium in ICRS-2 Model ($A^{\circ} < A'$)



unanticipated shock, the increase in the loan market interest rate diminishes the incentives to be unemployed. In an actual economy, this may correspond to situations where unemployed individuals face tighter liquidity constraints or an increased likelihood of being turned down for loans in a recession.[15] The employment response still leads to a larger labor elasticity compared to the standard RBC model, because of the indivisible labor. But the elasticity is still smaller compared to CRS, because of the incomplete risk sharing. As labor demand shifts backwards, hours will fall by more than wages and productivity, but it will not overstate this feature as in CRS. In the period following the shock, supply to the loan market rises and this increases the incentives to enjoy leisure and finance consumption through loans. Thus, while labor demand begins to return to its original value, labor supply actually shifts backwards and hours and wages move in opposite directions. Consequently, the contemporaneous correlation between productivity and hours falls and equilibrium hours and output may continue to fall after the technology shock. It is this channel of dampening the initial response of labor supply to aggregate shocks that causes changes in productivity to lead changes in hours worked over the business cycle.

[15] The idea that economic downturns may lead to a decrease in net worth and magnify agency costs and credit rationing has been emphasized in the business lending context by Bernanke and Gertler (1989), among others.

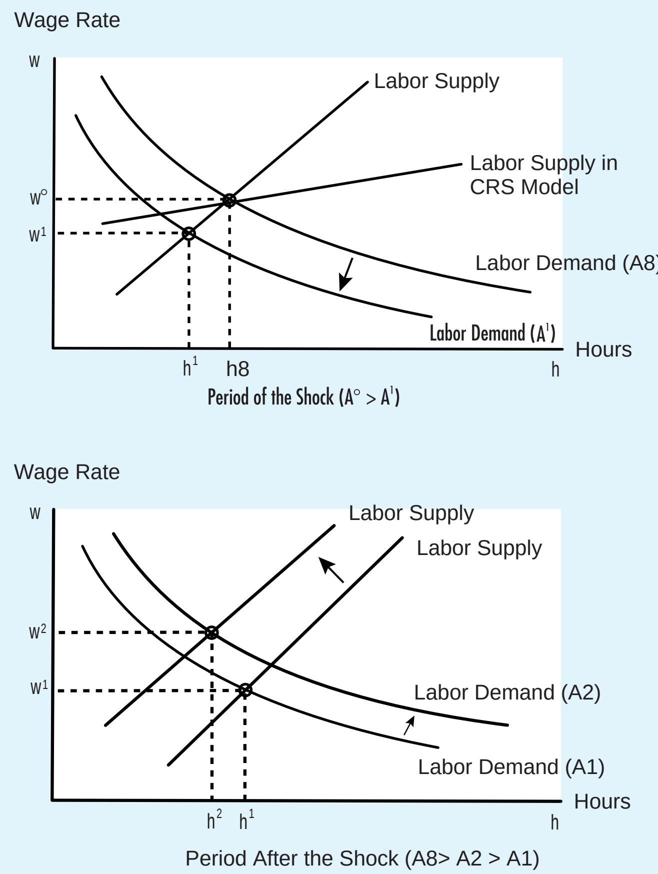
CONCLUSION

Real business cycle theory has demonstrated that a simple neoclassical model of economic growth with supply-side disturbances can have remarkable success in explaining important business cycle facts. This article presents some basic U.S. labor market facts and explains why the labor market predictions of the basic RBC model have been received by many with skepticism. It also shows how the inclusion of indivisible labor and unemployment into an RBC model can improve these labor market predictions. Finally, it suggests that a more explicit treatment of incomplete risk sharing may help resolve some of the model's more problematic labor market predictions. Among them are that productivity tends to lead hours over the cycle, the low hours-productivity contemporaneous correlation, and the high relative volatility of hours worked to productivity.

This paper also draws interesting parallels to the time-to-plan specification of Christiano and Todd (1996)—where capital goods are not productive until several periods after the investment decision is made—and Merz (1995), who incorporates labor market search into RBC models. All of these approaches, including our example of incomplete risk sharing, emphasize features of the economy that dampen the response of production factors to aggregate shocks. They also help in better matching the movement of hours and productivity to output and each other over the business cycle. The main idea behind our example simply is that not permitting unemployed individuals the same access to income and consumption opportunities as those employed significantly affects how aggregate labor supply reacts to uncertain economic shocks. The results in the paper suggest that an explicit treatment of frictions in both the labor and financial markets and their interactions may be a fruitful direction for future research when evaluating the labor market performance of market-clearing business cycle models.

Figure 17

Labor Market with Negative Technology Shock in ICRS-2 Model



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Appendix

This appendix formalizes the solution to the incomplete risk sharing model. The technology shock $A_t = exp(z_t)$ where z_t follows a stationary AR(1) process:

$$\text{(A1)} \qquad z_{t+1} = \rho z_t + \varepsilon_{t+1}$$

and ε_1 is a pure white noise disturbance with zero mean and constant variance σ_ε^2. Given $u(c_t, 1_t) = u(c) + V(1 - L)$ where $u(c) = ln(c)$ and $V(1 - L)$ the first-order conditions for $\{c_{1t}, c_{2t}, d_t\, b_{1t}, b_{2b}, n_t, k_{t+1}\}$ associated with maximizing equation 5 subject to equations 7 and 8 are given by:

$$\text{(A2)} \qquad u'(c_{1t}) = \lambda_{1t},$$

$$\text{(A3)} \qquad (1-n_t)u'(c_{2t}) = (1-n_t)\lambda_{1t} + \lambda_{2t},$$

$$\text{(A4)} \qquad E_{t-1}\{\lambda_{1t}(R_t - s) - \lambda_{2t}\} = 0,$$

$$\text{(A5)} \qquad \lambda_{1t} n_t R_1 b_{1t} = 0,$$

$$\text{(A6)} \qquad [\lambda_{2t} - \lambda_{1t}(1-n_t)R_t]b_{2t} = 0,$$

$$\text{(A7)} \qquad \begin{aligned} & u(c_{1t}) - uc_{2t} \\ & + \lambda_{1t}[c_{2t} - c_{1t} + R_t(b_{2t} - b_{1t}) + w_t L] \\ & = V(1) - V(1-L), \textit{ and} \end{aligned}$$

$$\text{(A8)} \quad \lambda_{1t} = \beta E_t\{\lambda_{1,t+1}(1 + r_{t+1} - \delta) + \lambda_{2t+1}r_{t+1}\},$$

where λ_1 and λ_2 are multipliers for the budget constraint given in equation 8 and the unemployed consumption constraint (equation 7). Notice from equations A2 and A3 that $\lambda_2 = (1-n_t)[u'(c_{2t}) - u'(c_{1t})]$. Thus, a necessary and sufficient condition for unemployment consumption constraint in equation 7 to bind is given by $c_{2t} < c_{1t}$. The time t-1 expectations operator in equation A4 indicates that d_1 is chosen before productivity shock z_t is realized. Notice that if $s = 0$, then the model is completely standard with $\lambda_{2t} = 0$ and $c_{2t} = c_{1t}$. From these we can immediately rule out several cases with regard to the borrowing decision of employed and unemployed individuals. It is straightforward to verify that a sufficient condition to rule out $b_{1t} > 0$ is given by $R_t > 0$. The case where $b_{1t} = b_{2t} = 0$ is possible if and only if complete risk sharing can be achieved without use of the loan market; however, this case can be ruled out quantitatively given the steady state consumption and income levels implied by the model parameterization. This leaves us with the most natural case of $b_{1t} = 0$ and $b_{2t} > 0$ Equations A2, A3, and A6 give us $R_t = [u'(c_{2t}) - u'(c_{1t})]/u'(c_{1t})$. Substituting these and the market-clearing conditions into equations A7, A8, and A4 gives

$$\text{(A9)} \qquad \begin{aligned} & u(c_{1t}) - u(c_{2t}) \\ & + u'(c_{1t})[c_{2t} - c_{1t} + w_t L] \\ & + [u'(c_{2t}) - u'(c_{1t})]\frac{d_t}{1-n_t} \\ & = V(1) - V(1-L), \end{aligned}$$

$$\text{(A10)} \quad u'(c_{1t}) = \beta E_t \left\{ \begin{aligned} & u'(c_{1,t+1})\left[1 + f_K\left(\begin{matrix} z_{t-1}, k_{t+1}, \\ n_{t+1}L \end{matrix}\right) - \delta\right] \\ & + f_K(z_{t+1}, k_{t+1}, n_{t+1}L)(1-n_{t+1}) \\ & [u'(c_{2,t+1}) - u'(c_{1,t+1})] \end{aligned} \right\}, \textit{ and}$$

$$\text{(A11)} \qquad E_{t-1}\left\{ \begin{aligned} & n_t[u'(c_{2t}) - u'(c_{1t})] \\ & -su'(c_{1t}) \end{aligned} \right\} = 0.$$

Equations A9, A10, and A11 give the efficiency condition for n_t, k_{t+1}, and d_t. To obtain some intuition behind these conditions we must first consider the case where d_t is chosen after the productivity shock. If $s = 0$, then $c_{1t} = c_{2t}$, and these conditions collapse to a standard RBC model with indivisible labor. While risk is still shared efficiently for $s > 0$, it is costly to participate in the loan market, and from equation A11, $c_{2t} < c_{1t}$, $R_t > 0$ and the unemployment consumption constraint in equation 7 binds. Quite intuitively, this binding constraint increases the marginal benefit of an additional worker and an additional unit of capital, as captured by the fourth term in equation A9 and the second term in the expectations operator in equation A10. Finally, if d_t is chosen before the productivity shock is revealed, the previous statements hold only in expected value terms because risk sharing will be incomplete. For example, if the productivity shock is unexpectedly high, then the unemployment consumption constraint in equation 7 binds less than expected, thereby implying a lower-than-average marginal benefit to additional workers and capital during the period of the shock. It is this feature that will generate quantitatively different results relative to the complete risk sharing case.

To be comparable to previous real business cycle studies (e.g. Hansen and Wright, 1992) we choose $\alpha = 0.36$, $\beta = 0.99$, $\sigma = 0.025$, $L = 0.53$, $\rho = 0.95$, and $\sigma_\varepsilon = 0.00721$. The transactions cost variable s is chosen to be 0.0058 so that the steady-state loan market interest rate corresponds to the rate of time preference. The models are solved by linearizing Euler equations A8, A9, and A10 about the model's steady state.