The Role of Agriculture in Aggregate Business Cycle Fluctuations†

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Abstract

The agricultural sector has certain distinctive features over the business cycle: it is more volatile than and not positively correlated with the rest of the economy and its employment is counter-cyclical. Because of these features and even though the agricultural sector represents less than 2% of the U.S. economy, we show that agriculture plays an essential role in understanding aggregate business cycles. The inclusion of agriculture into standard business cycle analysis resolves the longstanding problems of the standard theory in matching the observed volatility of aggregate labor and the correlation of aggregate labor and productivity (the so called "Dunlop-Tharshis" observation). In addition, the role of agriculture in the economy can account for the substantial differences observed in business cycle patterns across countries. This novel implication of the model is consistent with the systematic relationship observed between business cycle patterns and the share of agriculture across countries. Our theory has two important implications. First, the model implies that as the size of the agricultural sector falls, business cycle properties across countries should converge. Second, the role of agriculture provides a simple, measurable, and contrastable explanation for the historical properties of aggregate business cycles documented by Backus and Kehoe (1992).

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1 Introduction

The agricultural sector features singular properties during business cycles. As we document both for the U.S. and a sample of other OECD countries, the agricultural sector is more volatile than and not positively correlated with other sectors in the economy. In addition, agricultural employment is counter-cyclical. Because of these features and even though the agricultural sector represents less than 2% of the U.S. economy, we show in this paper that agriculture plays an essential role in understanding aggregate business cycles. The inclusion of an agricultural sector into standard business cycle analysis resolves the longstanding problems of the standard theory in matching the observed volatility of aggregate labor and the correlation of aggregate labor and productivity (the so called "Dunlop-Tharshis" observation). In addition, we show that the role of agriculture in the economy can account for the substantial differences observed in business cycle patterns across countries. This novel implication of the model is consistent with the systematic relationship observed between business cycle patterns and the share of agriculture across countries.

We show these results by introducing agriculture into an otherwise standard indivisible-labor real business cycle model where investment goods are produced in the non-agricultural sector. This simple extension of the neoclassical growth model has important and novel implications for aggregate business cycles. First, the model is able to account for the aggregate labor volatility and the correlation of aggregate labor and productivity observed in U.S. data. Differently from alternative models (see, for instance, Benhabib, Rogerson, and Wright, 1991; and Eichembaum and Christiano, 1992), our model does not attribute labor fluctuations to changes in hours, but instead the labor volatility in our model arises from employment fluctuations. Employment, not hours, accounts for most of the volatility in aggregate labor in the data. Moreover, our theory does not rely on unmeasured activities and shocks. Second, the share of agriculture in the economy can account for an important portion of the observed differences in aggregate business cycle patterns across countries (see, for example, Danthine and Donaldson, 1993 and Kollintzas and Fiorito, 1994).[1] This implication of the theory is consistent with the systematic relationship observed between the size of agriculture in the economy and its business cycle properties: agriculture intensive economies tend to feature high aggregate output fluctuations, low employment volatility, and low correlation of aggregate employment with output.

[1] For example, comparing Turkey with the U.S., where the agricultural share in employment is 30% and 2%, aggregate output fluctuations are 3.25 and 2.12, employment volatilities are 0.23 and 0.62, and the employment-output correlations are 0.13 and 0.82, respectively.

The standard indivisible labor model implies too much volatility of employment relative to the data because shocks to technology can only draw more labor from the non-employment pool. It also implies a near one correlation of the labor input with productivity because shocks to technology shift the labor demand along a stable labor supply. Because agricultural and non-agricultural outputs are not correlated in the U.S. economy, technology shocks across these sectors are likely not highly correlated. Therefore, in the model with agriculture a positive shock in one sector allows some labor to be drawn from the other sector instead of the non-employment pool. This reduces aggregate employment volatility relative to the standard indivisible-labor model and quantitatively matches the data. Labor reallocation across sectors also reduces the correlation of aggregate labor with productivity. To illustrate this point, suppose that in the face of a positive shock to agriculture, all additional labor to agriculture is drawn from non-agriculture. Clearly, the shock produces an improvement in average labor productivity, but no change in aggregate employment. At the other extreme, if all additional labor is drawn from non-employment the model implies a near one correlation of labor and productivity as in the standard one-sector model. As long as an increase in labor productivity induces labor reallocation across sectors the model implies a correlation of aggregate labor and productivity smaller than one.

A similar intuition applies to the cross-country implications of the model. In particular, the size of the agricultural sector matters for aggregate business cycle fluctuations because shocks to technology not only induce investment in order to smooth aggregate consumption over time but also they induce a reallocation of factor inputs across sectors. The relative cost/benefit of the trade off between intra vs. inter temporal decisions hinges crucially on the relative productivity of the agricultural sector. Because the agricultural sector is relatively more productive in agricultural intensive economies and because the sector produces no investment goods, agricultural intensive economies favor the intra temporal margin relatively more than less agricultural intensive economies. That is, positive shocks to agricultural production are accompanied by flows of capital and labor into agriculture in agricultural intensive economies. This correlation is weaker in less agricultural intensive economies. The relative trade off between intra vs. inter temporal decisions generates a distinct pattern of business cycle fluctuations: aggregate output fluctuates more and aggregate labor volatility is low in agricultural intensive economies. Moreover, for these economies, non-agricultural output fluctuates more and agricultural output fluctuates less relative to less agricultural intensive economies. This pattern of aggregate and sectoral fluctuations is consistent with the evidence across agricultural and less agricultural countries.

Our theory offers a simple and measurable hypothesis of the source of business cycle patterns across countries. These implications of the theory can be contrasted with data. Specifically, the model implies that, as the size of the agricultural sector falls, business cycle properties across countries should converge. In addition, since the structural transformation of economies implies a smaller role of the agricultural sector over time, historical data should show lower aggregate fluctuations in recent times. This is precisely the evidence documented by Backus and Kehoe (1992) in comparing the pre-war and post-war periods for the U.S. and other developed countries.

The role of agriculture in aggregate business cycles may prove useful in recent discussions regarding the importance of technology shocks in accounting for business cycle fluctuations (e.g. Galí, 1999 and Francis and Ramey, 2001). Not only the introduction of agriculture reconciles standard business cycle analysis with the data, but also the weather provides a natural source of technology shocks (even negative) in agriculture. Paraphrasing King and Rebelo (1999), this simple disaggregation in production of the standard model may prove useful in "resuscitating real business cycles". Our paper is also related to a small literature on sectoral business cycles, starting in Long and Plosser (1983) and more recent contributions in Huffman and Wynne (1999) and Horvath (2000). Differently from these papers we focus on agriculture and its role in cross-country business cycle implications.

The paper proceeds as follows. In the next section we document the properties of agriculture relative to other U.S. industries over the cycle and in a sample of OECD countries. We also document the main properties of business cycle fluctuations across countries and how these are related to the size of agriculture in the economy. In section 3, we follow Benhabib, Rogerson, and Wright (1991) in considering a two-sector real business cycle model with agriculture and non-agriculture. Section 4 presents the calibration of the benchmark economy and its properties. Section 5 reports quantitative experiments aimed at illustrating the role of agriculture in accounting for the business cycle facts across countries. In the last section we conclude.

2 Business Cycle Facts

In this section we document two important set of observations. First, we report the main business cycle regularities of agriculture, both across U.S. industries and in a panel of OECD countries. Second, we document important differences in business cycle properties across countries and how these are related to the agricultural share in the economy.

We use U.S. industry data from the National Income and Products Accounts and construct a panel of OECD countries using the National Accounts data published by the OECD. Due to data availability, we restrict our sample to annual frequencies. The data is de-trended using the Hodrick-Prescott filter with $\lambda = 100$. In what follows we report summary statistics for a subset of countries. The appendix includes a complete description of data sources, sample periods, definitions, and tables with all countries (Tables 14 to 16).

2.1 Evidence from U.S. Industries

The presumption that no private sectoral activity had counter cyclical properties lead researchers to dismiss the role of sectoral composition of output in aggregate business cycles (see, Benhabib, Rogerson, and Wright, 1991). We find that agricultural activity is not pro-cyclical.

We construct a panel data from the U.S. National Income and Product Accounts for a set of 10 sectors from 1987 to 2000. These observations are reported in Table 1. The first two columns report the output and employment shares in each sector and the next four columns report standard deviations of logged and filtered variables and correlation statistics of sectoral output and employment. We extract the following observations. First, agriculture and mining present the largest output fluctuations, while construction and agriculture are the most volatile sectors in employment. Second, the correlation of sectoral output with aggregate GDP is lowest in agriculture, mining, and government, and the same applies for employment. We warn the reader to consider the employment observations with caution because employment in this panel is defined as the number of employees and the incidence of self-employment is high in agriculture.

Since the sectoral output correlation with aggregate GDP can mask important relationships, Table 2 reports the correlation matrix of sectoral output for all U.S. industries. Agriculture is not positively correlated with other sectors in the economy. The highest correlation of agricultural activity is, perhaps not surprisingly, with the government sector. There are no other private industries with this property.

2.2 Cross-Country Agricultural Facts

The lack of pro-cyclical behavior of the agricultural sector arises also in a panel of OECD countries, where for most countries in the sample, the agricultural sector features counter cyclical properties. Table 3 presents a summary of statistics for an un-weighted average of

Table 1: U.S. Industry Cyclical Facts 1987-2000

Real GDP by Industry*	Mean s_y	Mean s_l	Std[ln(z)] Y_i	Std[ln(z)] L_i	Corr(z,y) Y_i	Corr(z,y) L_i
Agriculture, Forestry, and Fishing	1.75	1.62	4.61	2.07	0.04	0.78
- Farms	1.24	0.73	6.36	3.03	0.01	0.60
Mining	1.46	0.52	6.85	2.96	0.15	0.27
Construction	4.17	4.49	4.17	5.13	0.95	0.92
Manufacturing	16.75	15.28	3.49	1.64	0.81	0.80
Transportation and Public Utilities	8.07	4.94	1.44	1.34	0.08	0.86
Wholesale Trade	6.64	5.22	3.48	2.11	0.62	0.84
Retail Trade	8.73	17.23	3.39	1.45	0.94	0.77
Finance, Insurance, and Real State	18.86	5.73	2.17	1.50	0.78	0.81
Services	20.00	27.24	1.71	0.91	0.81	0.75
Government	4.26	17.73	2.42	1.00	−0.15	0.11
Aggregate	100.00	100.00	1.38	1.20	1.00	0.93

*Real Gross Domestic Product by Industry in Chained (1996) Dollars, 1987-2000, from the *Gross Domestic Product by Industry.* Industry Accounts Data. Bureau of Economic Analysis (http://www.bea.doc.gov/bea/dn2/gpox.html).

Table 2: Sectoral GDP Correlations

	Gross Domestic Product by Industry											
	GDP	AFF	Farm	Min	Con	Man	TPU	WhT	ReT	FIR	Ser	Gov
GDP	1.00	0.04	0.01	0.15	0.95	0.81	0.08	0.62	0.94	0.78	0.81	−.15
AFF		1.00	0.97	−.66	−.14	−.37	−.01	0.22	0.02	0.25	0.12	0.46
Farm			1.00	−.66	−.17	−.36	0.06	0.11	−.02	0.13	0.08	0.41
Min				1.00	0.32	0.48	−.37	0.16	0.20	−.22	−.06	−.63
Con					1.00	0.90	0.10	0.58	0.91	0.68	0.64	−.36
Man						1.00	0.11	0.37	0.82	0.50	0.44	−.59
TPU							1.00	−.53	−.03	0.00	0.25	0.25
WhT								1.00	0.73	0.71	0.42	−.11
ReT									1.00	0.82	0.70	−.27
FIR										1.00	0.69	0.14
Ser											1.00	0.36
Gov												1.00

AFF=Agriculture, Forestry, and Fishing; Farm=Farms; Min=Mining; Con=Construction; Man=Manufacturing; TPU=Transportation and Public Utilities; WHT=Wholesale Trade; ReT=Retail Trade; FIR=Finance, Insurance, and Real State; Ser=Services; Gov=Government.

Table 3: Agricultural Business Cycle Facts

	OECD Average		U.S.	
Variable	σ_x/σ_Y	$\rho(x, Y_n)$	σ_x/σ_Y	$\rho(x, Y_n)$
Y_n	1.06	1.00	1.02	1.00
Y_a	2.27	-.03	2.58	-.01
L	0.69	0.51	0.63	0.82
L_n	0.77	0.60	0.66	0.83
L_a	1.19	-.18	1.08	-.14

OECD countries and the U.S. In the appendix these observations are reported for all OECD countries. From Table 3 we extract the following agricultural facts:

1. Agriculture is not positively correlated with the rest of the economy.

   Agricultural employment is not correlated with non-agricultural output, in fact, for most countries it is negatively correlated. Agricultural output is also not correlated with non-agricultural output.

2. Agricultural activity fluctuates more than the rest of the economy.

   In average the value of agricultural output fluctuates two times more than the value of non-agricultural output, while agricultural employment fluctuates one and a half times more than non-agricultural employment, implying that agricultural labor productivity fluctuates almost three times more than non-agricultural productivity.

It is worthwhile emphasizing that even though the U.S. presents a small agricultural sector (agricultural output is 1.7% of aggregate GDP and agricultural employment is 2% of working age population), employment and output fluctuations in agriculture are twice as high as in non-agriculture, and both agricultural output and employment are negatively correlated with the non-agricultural sector. Moreover, there is abundant evidence of the counter-cyclical nature of agricultural employment in developing countries, for example, see Rozelle, Zhang, and Huang (2001) for evidence in rural China and Lee (1980) for evidence in Korea. Da-Rocha and Restuccia (2002) document similar properties of the agricultural sector in business cycles for regions in Spain.

2.3 Cross-Country Aggregate Differences

There are large differences in aggregate fluctuations across countries, in particular, aggregate fluctuations in output and employment differ by factors of 2. Table 4 reports business

Table 4: Cross-Country Business Cycle Facts

	σ_Y	σ_L/σ_Y	$\rho(L,Y)$
U.S.	2.12	0.63	0.82
Japan	2.19	0.36	0.68
Greece	2.27	0.46	-.36
Portugal	3.22	0.50	0.36
Turkey	3.25	0.23	0.13

cycles statistics for a small set of countries. Output fluctuations, measured as the standard deviation of the log, are as high as 3.25 in Turkey and 3.22 in Portugal, and as low as 1.80 in Belgium and 1.81 in Denmark. Employment volatility, defined as the standard deviation of the log of employment relative to output, is as high as 0.63 in the U.S. and as low as 0.23 in Turkey. These differences are systematic in the sense that countries with low employment volatility tend to have high aggregate output fluctuations. Moreover, the correlation of aggregate employment and output is as high as 0.82 in the U.S. and as low as 0.13 in Turkey and -0.36 in Greece. These cross-country business cycle observations are consistent with previous findings in the literature (see Danthine and Donaldson, 1993 and Kollintzas and Fiorito, 1994).

A closer look at the aggregate fluctuations across countries reveals a link between these observations and the share of agriculture in economic activity. Figures 1, 2, and 3 document that countries with a large agricultural sector tend to have high aggregate output fluctuations, low employment volatility, and low correlation between aggregate employment and output. Our conjecture is that the characteristics of agricultural production are responsible for this particular pattern.

We emphasize that the same business cycle patterns of high output fluctuations, low employment volatility, and low correlation of employment and output holds for agricultural intensive regions in Spain, as we document in a related work (see Da Rocha and Restuccia, 2002). Regional comparisons (as opposed to cross-country comparisons) are important since economic activity occurs in a similar institutional environment, in particular, similar labor market institutions that are often cited as the source of differences in labor market fluctuations across countries (see, for example, Danthine and Donaldson, 1993 and Maffezzoli, 2001).

Figure 1: Cross-Country GDP Fluctuations and Agriculture

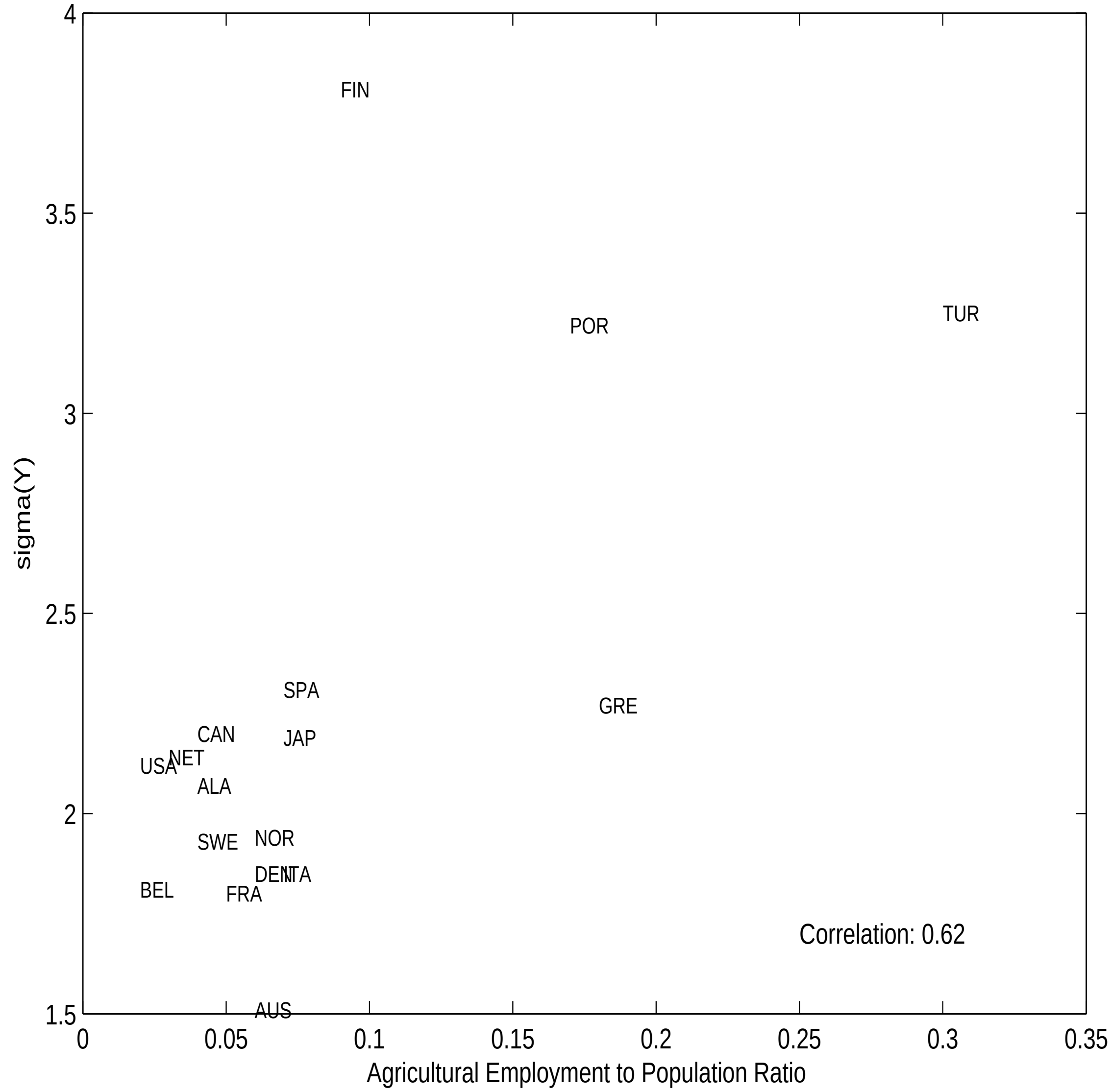


Figure 2: Cross-Country Employment Volatility and Agriculture

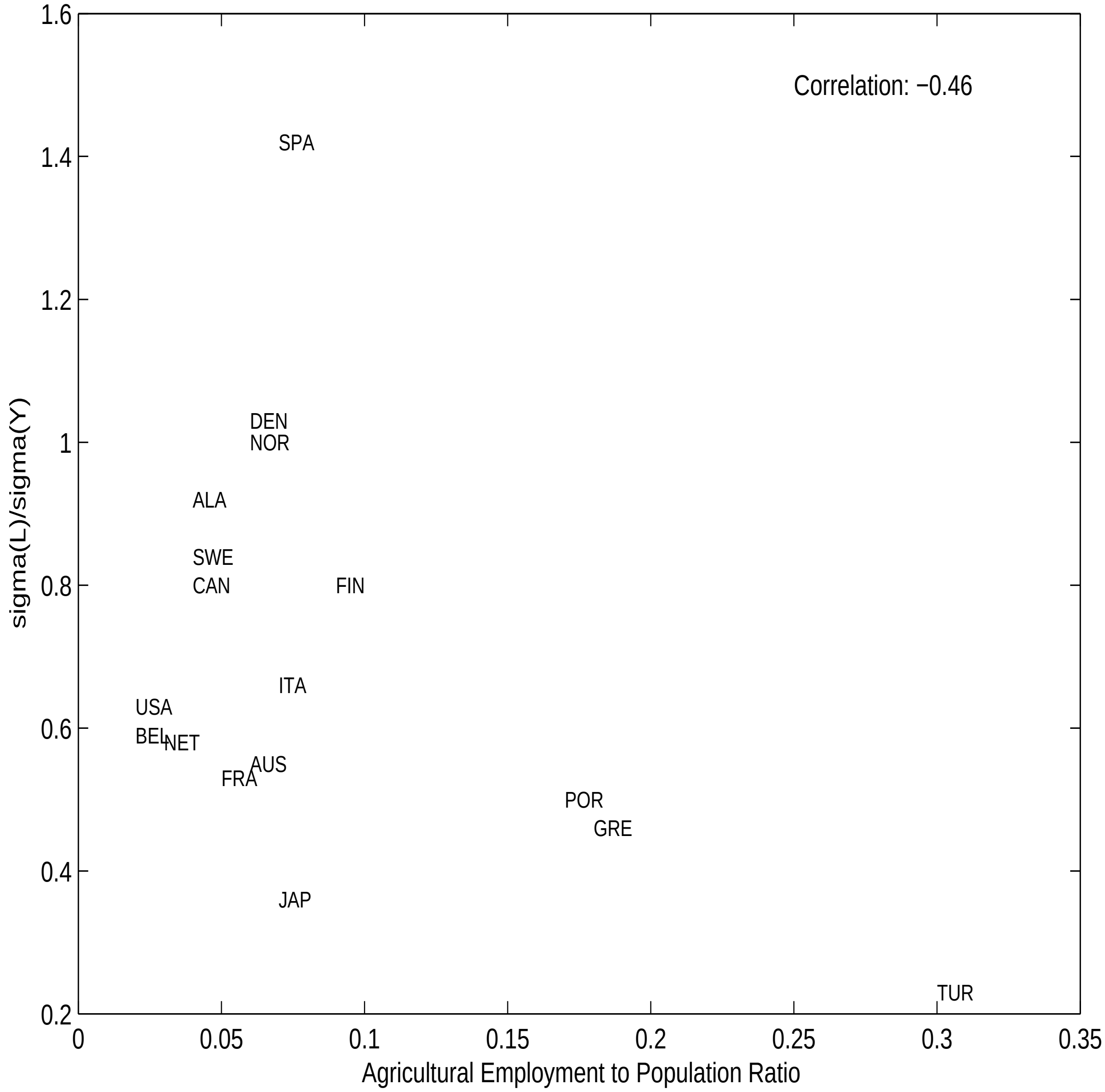
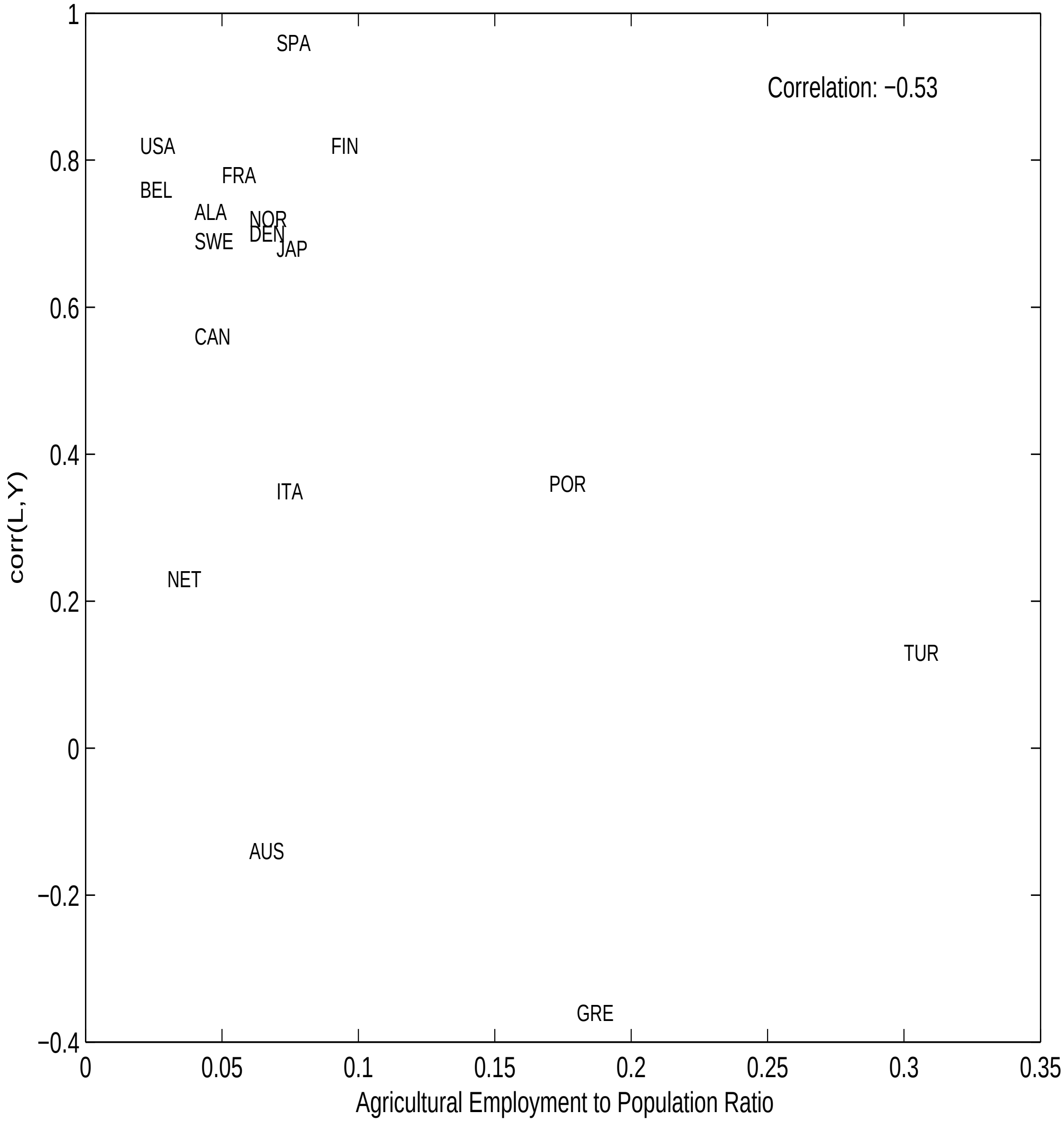


Figure 3: Cross-Country Correlation of Employment and GDP



3 The Economic Environment

We follow Benhabib, Rogerson and Wright (1991) in considering a two-sector real business cycle model with agriculture and non-agriculture. We calibrate the benchmark economy to aggregate and sectoral properties of the U.S. economy. In what follows we discuss the economic environment in more detail.

3.1 General Description

Feasibility There are two goods in our economy, agriculture (a) and non-agriculture (n). The non-agricultural output Y_n can be allocated to non-agricultural consumption C_n and investment in physical capital X,

$$C_{n,t} + X_t \leq Y_{n,t},$$

where capital follows a standard accumulation equation,

$$K_{t+1} = (1 - \delta)K_t + X_t.$$

The agricultural output Y_a can only be allocated to agricultural consumption C_a,

$$C_{a,t} \leq Y_{a,t}.$$

The capital stock can be allocated to either sector,

$$K_{n,t} + K_{a,t} \leq K_t.$$

Technologies Output in each sector is produced with a constant returns to scale production function. The non-agricultural technology requires physical capital and labor services as inputs while the agricultural technology requires physical capital, labor, and land. Fluctuations are driven by shocks to technologies. Output in each sector is given by,

$$Y_n = \gamma_n^t \lambda_n e^{z_{n,t}} K_n^{\theta} H_n^{1-\theta},$$

$$Y_a = \gamma_a^t \lambda_a e^{z_{a,t}} K_a^{\mu} H_a^{\phi} T^{1-\mu-\phi},$$

where for each sector $i \in \{a, n\}$, $\gamma_i \geq 1$ is an exogenous growth rate of productivity, K_i is the physical capital input, H_i is the labor input, T is a fixed supply of land, λ_i is a time invariant technology parameter, and z follows a vector auto-regressive process described by

$$z_{t+1} = \rho z_t + \varepsilon_{t+1},$$

where $z = [z_n, z_a]'$ is a vector with the non-agricultural and agricultural shock and ε is normally distributed with zero mean and variance-covariance matrix Ω.

Population and Preferences The economy is populated by a measure of identical households that grows over time at an exogenous gross rate η. We normalize the initial population measure to one. The representative household has preferences over sequences of per-capita consumption C_t/L_t and leisure l_t for each member of the household described by,

$$\sum_{t=0}^{\infty} \beta^t u\left(\frac{C_t}{L_t}, l_t\right) L_t,$$

where β is the time discount factor. The per-period utility function is defined as,

$$u\left(\frac{C_t}{L_t}, l_t\right) = b \log\left(\frac{C_t}{L_t}\right) + (1-b)\log l_t,$$

and aggregate consumption as,

$$C_t = \left[aC_{n,t}^e + (1-a)C_{a,t}^e\right]^{\frac{1}{e}}.$$

Each member of the household is endowed with one unit of productive time each period. Since our data is restricted to employment in each sector we assume there is indivisibility in labor hours. This assumption is not too restrictive in the sense that a large portion of fluctuations are due to changes in employment and not in hours worked. A household works a given number of hours in either sector or does not work. Because the commodity space is not convex with this restriction, we introduce lotteries as in Rogerson (1988). Hansen (1985) introduces Rogerson's lotteries in a dynamic real business cycle model. With probability π_n, the household works $\bar{h}_n$ hours in the non-agricultural sector, with probability π_a the household works $\bar{h}_a$ hours in the agricultural sector, and with probability $1 - \pi_a - \pi_n$ the household does not work. This feature allows us to write the problem in terms of employment shares in each sector, since in equilibrium, π_n is the employment to population ratio in non-agriculture, π_a is the employment to population ratio in agriculture, and $(1 - \pi_n - \pi_a)$ is the non-employment to population ratio.

3.2 Definition of Equilibrium

It is convenient to write the problem in efficiency units of labor, that is, all growing variables are divided by the population size and the exogenous productivity growth $\gamma^t = \gamma_n^t$, and denote these variables with lower case letters.[2] Because there are no externalities or distortions and the choice set with lotteries is convex, we think of a benevolent social planner determining allocations.

An equilibrium in this environment is a sequence of history contingent allocations,

$$\{c_{a,t}, c_{n,t}, k_{t+1}, k_{n,t}, \pi_{a,t}, \pi_{n,t}\}_{t=0}^{\infty},$$

that solves the following stochastic planning problem,

$$\max E_0 \sum_{t=0}^{\infty} \widehat{\beta}^t \left\{ \frac{b}{e} \log \left[a c_{n,t}^e + (1-a) c_{a,t}^e \right] + (1-b) \left[\pi_{n,t} \log(1-\bar{h}_n) + \pi_{a,t} \log(1-\bar{h}_a) \right] \right\},$$

subject to

$$c_{n,t} + \eta\gamma k_{t+1} - (1-\delta)k_t = \lambda_n e^{z_{n,t}} {k_{n,t}}^{\theta} (\pi_{n,t}\bar{h}_n)^{1-\theta},$$

$$c_{a,t} = \lambda_a e^{z_{a,t}} {k_{a,t}}^{\mu} (\pi_{a,t}\bar{h}_a)^{\phi} t^{1-\mu-\phi},$$

$$k_t = k_{n,t} + k_{a,t},$$

$$z_{t+1} = \rho z_t + \varepsilon_{t+1},$$

where γ and η are the gross rates of productivity and population, and $\widehat{\beta} = \beta\eta$.

In our environment with $\varepsilon_t = 0$ for all t, a steady state equilibrium is given by a constant sequence of allocations in the set $\{c_a, c_n, k, k_n, \pi_a, \pi_n\}$.

[2] Productivity growth in agriculture γ_a is assumed so that the shares of agriculture in output and employment are constant in a deterministic steady state of the economy. This requires $\gamma_a > \gamma_n$ because of the presence of the fixed factor land. We argue that the computational and expositional benefits associated with our focus on fluctuations around a stationary agricultural share outweigh the costs since for the period under consideration agricultural shares have not changed dramatically. This would of course not be true in a study of the historical properties of business cycles.

3.3 Characterization

In the steady state of our economy without uncertainty, there are six equilibrium conditions that we enumerate below:

$$k_n = \left[\frac{\xi + \delta}{\theta \lambda_n}\right]^{\frac{1}{\theta - 1}} \pi_n \bar{h}_n, \tag{1}$$

$$\frac{a}{1-a} \frac{c_n^{e-1}}{c_a^{e-1}} = \frac{\mu(y_a/k_a)}{\theta(y_n/k_n)}, \tag{2}$$

$$\frac{b}{1-b} + \frac{\pi_n \log(1 - \bar{h}_n)}{(1-\theta) y_n} \frac{a c_n^e + (1-a) c_a^e}{a c_n^{e-1}} = 0, \tag{3}$$

$$\frac{b}{1-b} + \frac{\pi_a \log(1 - \bar{h}_a)}{\phi y_a} \frac{a c_n^e + (1-a) c_a^e}{(1-a) c_a^{e-1}} = 0, \tag{4}$$

$$c_{n,t} + (\eta\gamma + \delta - 1)(k_n + k_a) = y_n, \tag{5}$$

$$c_{a,t} = y_a, \tag{6}$$

where $\xi = \dfrac{\eta\gamma}{\widehat{\beta}} - 1$, $\Phi_i = -\dfrac{\log(1 - \bar{h}_i)}{\bar{h}_i}$, $h_i = \pi_i \bar{h}_i$ for $i \in \{n, a\}$, $y_n = \lambda_n e^{z_{n,t}} {k_{n,t}}^{\theta} (\pi_{n,t} \bar{h}_n)^{1-\theta}$, and $y_a = \lambda_a e^{z_{a,t}} {k_{a,t}}^{\mu} (\pi_{a,t} \bar{h}_a)^{\phi} t^{1-\mu-\phi}$. These equations are fairly intuitive. Equation (1) is the Euler condition for capital accumulation. Equation (2) relates the marginal returns of capital allocated to agriculture and non-agriculture with the marginal utility of consumption from each good. Equations (3) and (4) relate to the static choice between consumption of agricultural and non-agricultural goods and leisure, finally, (5) and (6) are the resource constraints. Equations (1) to (6) and the two production functions define a system of 8 equations in 8 unknowns $\{c_n, c_a, \pi_a, \pi_n, k, k_n, y_a, y_n\}$, that is used to solve for the steady state.

The share of agriculture in aggregate output in the economy s_a, is defined as,

$$s_a \equiv \frac{p_a y_a}{p_a y_a + y_n}, \tag{7}$$

where p_a is the price of the agricultural good in terms of the non-agricultural good

$$p_a = \frac{(1-a)c_a^{e-1}}{ac_n^{e-1}}. \tag{8}$$

Using equations (2), (3), (4), (7), and (8) we can write the allocation between agricultural and non-agricultural goods in terms of observed data: the share of agricultural goods in GDP, s_a, and the employment to population ratio of each sector, π_a and π_n,

$$(1-\mu) = \frac{1-s_a}{s_a}\frac{\pi^a}{\pi^n}(1-\theta)\frac{\log(1-\bar{h}_a)}{\log(1-\bar{h}_n)}. \tag{9}$$

Finally we write k_a and λ_a as

$$k_a = \frac{s_a}{1-s_a}\frac{\mu}{\theta}k_n, \tag{10}$$

$$\lambda_a = \frac{s_a y_n}{p_a \bar{y}_a (1-s_a)}. \tag{11}$$

These equations are useful in our calibration strategy in the next section.

4 Agriculture in the Benchmark Economy

4.1 Calibration

We calibrate the model to U.S. observations as our benchmark using both aggregate and sectoral data, following a procedure described in Prescott (1986) and Cooley and Prescott (1995).

Given the limitations of the data for a large cross section of OECD countries (in particular sectoral data on employment) the length of a period is assumed to be one year. The following parameter values are determined directly by U.S. data: the exogenous population growth η is 1.012% from the average annual growth of working-age population, the exogenous productivity growth γ is 1.016% from the average annual growth of GDP per working-age person, the non-agricultural capital income share θ is 0.4 (including consumer durables and government capital), the number of hours in non-agriculture $\bar{h}_n$ is 0.5 from Hansen (1985), the labor income share in agriculture ϕ is 0.1 from an average of employment compensation relative to GDP adjusted for proprietor's income in the farm sector for the period 1980-1998 from the U.S. Bureau of Economic Analysis, the land income share in agriculture $1-\phi-\mu$ is 0.1 from estimates in Hayami and Ruttan (1985), the total factor productivity parameter in non-agriculture λ_n is normalized to 1. We also normalize the supply of land T to one.[3] Finally, the persistence matrix ρ and the standard deviation of non-agricultural shocks σ_n are estimated using maximum likelihood with sectoral Solow residuals computed from U.S. data (Economic Report of the President for the years 1959 to 2000). In particular the Solow residuals are computed as,

$$z_i = \log(RGDP_i) + \log(p_i) - \xi_i \log(L_i),$$

where for each $i \in \{a, n\}$ $RGDP_i$ is real GDP in sector i (in 1996 dollars), p_a is the relative price of agriculture from price deflators (with the non-agricultural price normalized to one), L_i is employment in sector i, and $\xi_n = (1 - \alpha)$ and $\xi_a = \phi$. The estimated parameters are as follows,

$$\hat{\rho} = \begin{bmatrix} 0.93 & -0.05 \\ 1.22 & 0.57 \end{bmatrix},$$

and $\hat{\sigma}_n = 1.5\%$.

The following 8 parameters: the capital depreciation rate δ, the time discount factor β, the hours worked in agriculture $\bar{h}_a$, the productivity parameter in agriculture λ_a, the preference parameter for leisure b, the parameter governing the elasticity of substitution in consumption between agricultural and non-agricultural goods e, and the standard deviation of the agricultural shock σ_a; are chosen to jointly match the following 8 targets: an investment-output ratio of 25%, a capital-output ratio of 3.3, an agricultural employment share $\pi_a = 0.02$, an agricultural output share $s_a = 0.02$, a non-agricultural employment share $\pi_n = 0.64$, a standard deviation of log agricultural output $\sigma_{y_a} = 5.48$, a correlation of agricultural labor and non-agricultural output $\rho(L_a, Y_n) = -0.14$, and an agricultural and non-agricultural output correlation $\rho(Y_a, Y_n) = -0.01$. Finally, the preference parameter of the share of agriculture in the consumption basket a is set to 0.5 but in the appendix we show that this choice has no impact on the results of the paper. A summary of calibrated parameters values and targets is presented in Table 5. In the appendix we report the sensitivity of the results to changes in some of these parameters.

[3] Although the TFP parameter in agriculture could be re-written as $\hat{\lambda}_a = \lambda_a T^{1-\mu-\phi}$, introducing land into the environment is important because it allows for the sectoral composition of output to have an impact in the aggregate reproducible capital intensity in the economy.

Table 5: Benchmark Parameter Values

Parameter		Data U.S.
$\bar{h}_n$	0.5	Hansen (1985)
γ	1.016	GDP per capita growth rate
η	1.012	Population growth rate
θ	0.4	Capital income share
ϕ	0.1	U.S. Bureau of Economic Analysis (1980-1998)
$1-\phi-\mu$	0.1	Hayami and Ruttan (1985)
ρ and σ_n	see text	Sectoral Solow residuals U.S. data (1956-2000)
Parameter		Targets
$\lambda_{n,t}$	1.0	Normalization
δ	0.05	Investment rate 25%
β	0.9575	Capital-output ratio 3.3
$\bar{h}_a$	0.07	Ag. employment $\pi_a = 0.02$
$1000 \times \lambda_a$	0.04	Ag. output share $s_a = 0.02$
b	0.36	Non-Ag. employment $\pi_n = 0.64$
σ_a	0.014	Ag. output fluctuations $\sigma_{y_a} = 5.48$
$corr(\varepsilon_n, \varepsilon_a)$	-0.15	$\rho(L_a, Y_n) = -0.14$
e	0.8	$\rho(Y_a, Y_n) = -0.01$
a	0.5	Sensitivity analysis

4.2 Results of the Benchmark Economy

We compute decisions rules and business cycle statistics following the linear quadratic procedure described in McGrattan (1990). Table 6 presents a summary of business cycle statistics for the U.S. data and the benchmark economy. The calibrated economy roughly matches the data in important dimensions. First, the aggregate economy fluctuates as much as in the data (2.00 in the model vs. 2.12 in the U.S. data). Second, aggregate employment volatility and the volatility of employment relative to labor productivity are close to the data (0.65 and 1.55 in the model vs. 0.61 and 1.05 in the data) . Third, the correlation of aggregate employment and output and aggregate employment and labor productivity match very closely the data (0.80 and 0.36 in the model vs. 0.82 and 0.30 in the data).[4]

[4]If instead we use the entire stochastic process for the shocks implied by our sectoral residuals, the results of the benchmark economy are even closer to the aggregate data: the standard deviation of output is 2.11 (2.12 in the data) and the correlation of aggregate employment with output is 0.81 (0.82 in the data). However, the model fails to reproduce the sectoral output and employment correlations observed in the data. Given that our estimates of Solow residuals do not use data for capital stocks, this omission can seriously affect the correlation of innovations of the shocks. Moreover, our main objective is to look at the cross-country implications of agricultural production in business cycles and hence the importance of generating a benchmark economy consistent with the sectoral facts. Summary results of these simulations

Table 6: Business Cycles in Benchmark Economy

	U.S. Data			B.E.		
	σ_x	σ_x/σ_y	$\rho(x,y)$	σ_x	σ_x/σ_y	$\rho(x,y)$
Output	2.12	1.00	1.00	2.00	1.00	1.00
Employment	1.34	0.63	0.82	1.30	0.65	0.80
Non-Ag. Employment	1.39	0.66	0.83	1.47	0.73	0.75
Ag. Employment	2.28	1.08	-0.14	6.85	3.42	-0.04
Ag. Output Share	5.81	2.74	-0.34	7.79	3.88	-0.20
	σ_x	σ_x/σ_y	$\rho(x,y_n)$	σ_x	σ_x/σ_y	$\rho(x,y_n)$
Non-Ag. Employment	1.39	0.66	0.82	1.47	0.73	0.78
Ag. Employment	2.28	1.08	-0.14	6.85	3.42	-0.10
Ag. Output	5.48	2.56	-0.01	6.85	3.42	0.09
Non-Ag. Output	2.16	1.02	1.00	2.09	1.04	1.00

The introduction of agriculture into the analysis of aggregate business cycles reconciles the implications of the standard theory relative to data in two important dimensions: the relative volatility of aggregate employment and the correlation of aggregate employment with output and labor productivity. While the indivisible-labor model of Hansen (1985) generates too much volatility in employment relative to the data, agriculture reduces the volatility of employment making it much closer to the data (1.55 in the model vs. 1.05 in the data). The mechanism by which employment volatility in our model resembles the data is similar to the channel emphasized by Benhabib, Rogerson, and Wright (1991), namely intra temporal labor reallocation across sectors, however, labor re-allocation across sectors has very different aggregate consequences in our model compared to the household production model for two reasons. First, intra temporal substitution of labor reduces aggregate employment volatility in our model while it increases measured labor volatility in the home production model. Second, the household production model attributes the labor volatility to changes in labor hours between market and non-market activities, while our model attributes labor fluctuations to employment changes. Employment, not hours, accounts for most of the volatility in aggregate labor in the data.

Moreover, the intra temporal reallocation of labor across sectors reduces the correlation of aggregate employment with output and productivity. Christiano and Eichembaum (1992) estimate that by correcting for measurement error, the correlation of aggregate employment and labor productivity is around 0.2 (and perhaps as high as 0.4). The benchmark econ-

are available from the authors upon request.

omy produces a correlation between labor and productivity of 0.36. Contrary to Benhabib, Rogerson, and Wright (1991) and Christiano and Eichembaum (1992), our model is able to reconcile the standard theory with data in this dimension without relying on unmeasured activities and policy shocks.

These implications of the benchmark model are important since significant departures from the standard framework have been motivated by the failure of the model in these dimensions (see for instance Galí, 1999).

5 Quantitative Cross-Country Implications

In this section we explore the aggregate business cycle implications of the agricultural share in the economy. In particular, in this section we ask: Can the importance of agriculture in economic activity account for the differential pattern of business cycles across countries? The main finding in this section is that the size of agriculture in the economy can account for around half of the aggregate fluctuation differences across countries and the main patterns of aggregate labor market facts.

These results should not be overlooked. A large number of alternative models representing important departures from the standard framework have been explored to account for the labor market observations, but not a single explanation has been able to account for the aggregate fluctuations and labor market observations at the same time. In fact, Danthine and Donaldson (1993) write "...labor market behavior is substantially different across countries, most likely reflecting distinct cultural and institutional arrangements. It is unlikely that any single model formulation alone will be able to account for this wide range of phenomena." Our results suggest that major departures from standard theory, such as non-Walrasian labor markets, may not be necessary once the role of agriculture in business cycles is taken into account.

5.1 Description of Experiments

A set of experiments is designed to illustrate the role of agriculture in aggregate business cycle patterns across countries. To this end, we modify parameter values relating to the agricultural technology and preference for leisure in order to generate steady state economies with larger shares of agriculture than in the benchmark economy. Following our calibration procedure for the benchmark economy, for each experiment we choose the productivity parameter in the agricultural technology λ_a, the number of hours in agriculture $\bar{h}_a$, and the

Table 7: Calibration of Experiments

Targets	B.E.	Experiments 1	2	3	4
s_a	0.02	0.05	0.10	0.15	0.20
π_a	0.02	0.10	0.20	0.20	0.30
π_n	0.64	0.64	0.44	0.35	0.30
Parameters					
b	0.36	0.36	0.29	0.25	0.23
$p\lambda_a$	0.18	0.20	0.21	0.21	0.22
$\bar{h}_a$	0.07	0.04	0.03	0.04	0.03

preference parameter for leisure b to reproduce the following targets: (i) the output share of agriculture s_a, (ii) the employment to population ratio in agriculture π_a, and (iii) the employment to population ratio in non-agriculture π_n. We assume that the stochastic process of shocks remains the same across all experiments.

We consider four stylized experiments. First, we consider an economy like Japan, where the output share and employment ratio in agriculture are somewhat higher than in the U.S. with a lower non-employment ratio. Second, we consider an economy similar to Portugal, where the agricultural sector is even more important than in Japan, but the employment ratio in non-agriculture is lower. Third, we consider an economy similar to Greece, where the agricultural sector is large and the non-employment ratio is high. Finally, the fourth experiment resembles an economy like Turkey, where the agricultural sector is very large, non-agricultural employment and non-employment are low. The values for the targets and the resulting calibrated parameter values are reported in Table 7.

Table 8 summarizes the results of the experiments along with the results for the benchmark economy. Recall that as the experiment number increases, the size of agriculture in the economy increases. These experiments show that the agricultural sector in the economy can account for about half of the observed business cycle differences between Turkey and the U.S. In particular, as the size of the agricultural sector increase:

1. The aggregate economy fluctuates more. The experiment economy 4 fluctuates 36% more than the benchmark economy (2.01 vs. 2.74), which represents half of the difference in aggregate output fluctuations observed between the U.S. and Turkey.[5]

[5]Conesa, Díaz-Moreno, and Galdón-Sánchez (2002) assess quantitatively the cross-country implications of the home production model for aggregate fluctuations. Although successful in accounting for the aggregate

Table 8: Results of the Experiments

	B.E.	Experiments 1	2	3	4
π_a	0.02	0.10	0.20	0.20	0.30
σ_Y	2.01	2.13	2.38	2.58	2.74
σ_L	1.30	1.09	1.11	1.11	1.33
σ_L/σ_Y	0.65	0.51	0.47	0.43	0.49
$\rho(L,Y)$	0.80	0.90	0.74	0.79	0.52
K/Y	3.36	3.46	3.62	3.79	3.95
h_T	0.32	0.32	0.23	0.18	0.16
Rel. Y/L	1.00	0.93	0.79	0.76	0.66

2. The aggregate employment fluctuates about the same, but relative to output, the aggregate employment volatility falls from 0.65 in the benchmark economy to 0.49 in experiment 4. This is more than half the difference in employment volatility observed between Turkey and the U.S.

3. The aggregate employment is less correlated with output. In experiment 4, the employment and output correlation is 0.52 relative to 0.82 in the benchmark economy, while this correlation is 0.82 and 0.13 in the U.S. and Turkey respectively.

To summarize, the experiments illustrate that the model with agriculture is able to generate the main patterns of aggregate business cycles across countries, namely the high aggregate output fluctuations, the low volatility of employment, and the low correlation of employment and output observed in agricultural intensive countries.

The intuition for why agricultural intensive economies in the model generate these aggregate business cycle patterns can be illustrated by looking at a property of the model that has not been discussed before: the model implies an almost perfect correlation between output and factor inputs allocated to the production of agricultural goods both in the benchmark economy and in agricultural intensive economies. However, while in agricultural intensive economies the correlation between output and factor inputs allocated to the production of non-agricultural goods is also high, this correlation is much lower than one in the benchmark economy, the correlation between output and capital is $\rho(y_n, k_n) = 0.54$ and between output and labor hours is $\rho(y_n, \pi_n \bar{h}_n) = 0.78$ (see Table 9).

fluctuations differences across countries, the labor market implications of this theory are inconsistent with the cross-country evidence, as discussed in Section 4.

Figure 4: Sectoral Output and Capital in the Benchmark Economy

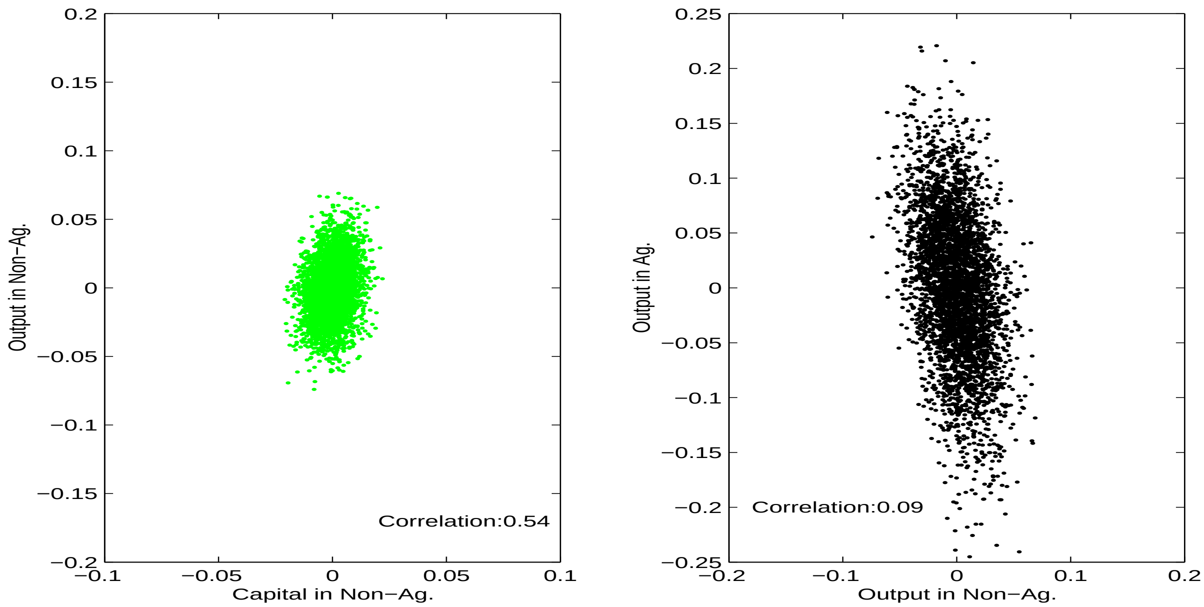


Figure 5: Sectoral Output and Capital in an Agricultural Intensive Economy

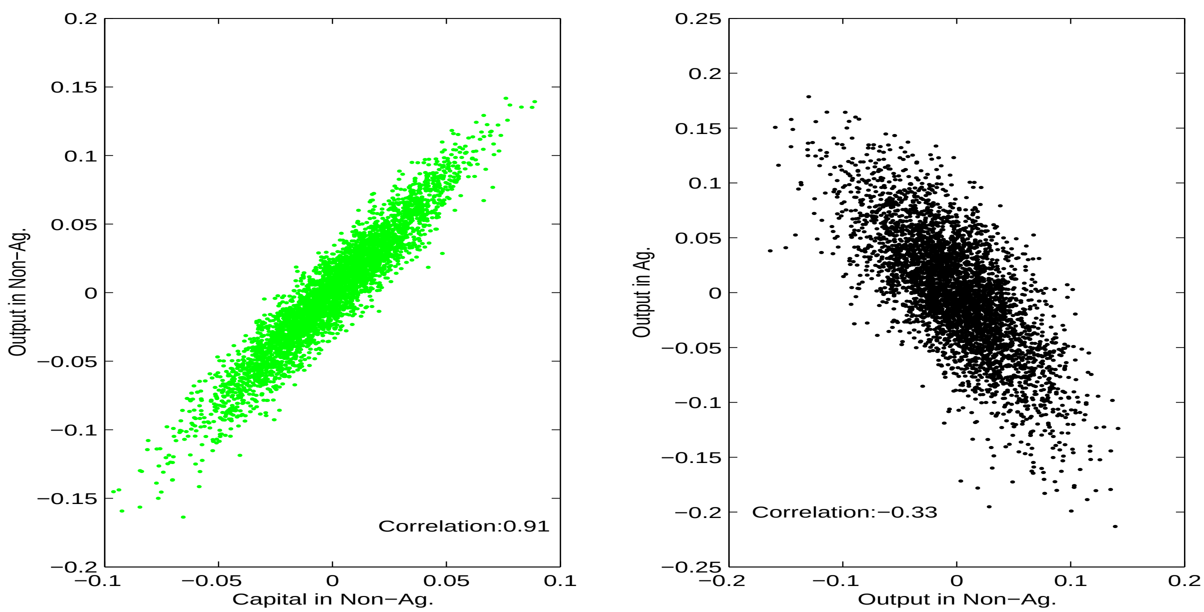


Table 9: Sectoral Cross-Country Implications

x	B.E.	Experiments 1	2	3	4
		σ_x			
y_n	2.07	2.41	3.03	3.70	4.33
y_a	6.81	6.58	6.23	5.85	5.36
k_n	0.62	0.71	1.25	1.90	2.55
k_a	8.11	7.89	7.51	7.11	6.58
h_n	1.45	1.82	2.50	3.21	3.87
h_a	6.81	6.58	6.23	5.82	5.31
		σ_x/σ_y			
y_n	1.05	1.13	1.28	1.43	1.58
y_a	3.44	3.10	2.63	2.26	1.96
k_n	0.31	0.34	0.53	0.74	0.93
k_a	4.10	3.71	3.17	2.75	2.41
h_n	0.73	0.86	1.06	1.24	1.41
h_a	3.44	3.10	2.63	2.25	1.94
		$\rho(x, y_n)$			
y_n	1.00	1.00	1.00	1.00	1.00
y_a	.09	−.02	−.17	−.27	−.33
k_n	.54	.62	.76	.86	.91
k_a	−.11	−.22	−.37	−.48	−.54
h_n	.78	.80	.85	.89	.91
h_a	−.10	−.21	−.37	−.47	−.54

$h_n = \pi_n \bar{h}_n$; $h_a = \pi_a \bar{h}_a$

Figures 4 and 5 illustrate this differential property of sectoral fluctuations by documenting a series of filtered simulations for the benchmark economy and for an agricultural intensive economy. As mentioned before, non-agricultural output is less correlated with factor inputs in the benchmark economy. This creates a weak correlation of sectoral output in the benchmark economy (0.09) while the correlation is stronger in the agricultural intensive economy (-0.33). It is worthwhile emphasizing that these figures also show that non-agricultural output fluctuates much less in the benchmark economy than in the agricultural intensive economy.

The intuition for these patterns is quite simple. In the standard model, shocks to technology are propagated by the inter temporal substitution of consumption as a way of smoothing consumption over time. With agricultural production, intra temporal substitution decisions are possible but investment goods are only produced in the non-agricultural sector. Hence, when there is a positive shock in non-agriculture, factor inputs are allocated to this sector and investment occurs, but when there is a positive shock to agriculture, not all resources flow to this sector, as investment must occur in non-agriculture. Because, agriculture is a relative unproductive sector in the benchmark economy the cost associated with resources not flowing to the booming sector is not too high. In agricultural intensive economies, the agricultural sector is relatively more productive and the cost associated with not reallocating resources to the booming sector is high. Therefore, intra temporal substitution of factor inputs is exercised to a lesser extent in agricultural intensive economies relative to the benchmark economy. This pattern of inter vs. intra temporal substitution decisions implies that agriculture fluctuates less and non-agriculture fluctuates more in agricultural intensive economies than in the benchmark economy. This pattern of sectoral output fluctuations between the benchmark economy and agricultural intensive economies is consistent with the sectoral cross-country evidence. This channel of business cycle fluctuations is radically different from the simple argument that agricultural economies fluctuate more because agricultural output is more volatile. On the contrary, *weather does not matter* for aggregate fluctuations, if anything fluctuations in agriculture are reduced in agricultural economies. Instead, our results suggest that agricultural intensive economies fluctuate more because of non-agriculture. The increase in its fluctuations more than compensates the reduction of fluctuations in agriculture.

6 Conclusions

This paper documents an important fact regarding the agricultural sector during cycles: its employment and output are not pro-cyclical in the U.S. but in many countries its economic activity is highly counter cyclical. The behavior of agriculture during cycles improves the quantitative implications of the standard real business cycle model, specially regarding the labor market facts: the volatility of aggregate employment and the correlation of employment with labor productivity and output. In addition, the model accounts for a large portion of the cross country differences in aggregate output and the labor market fluctuations. The model is consistent with the sectoral fluctuations and the sectoral co-movement patterns observed across countries: agriculture fluctuates less and non-agriculture more and agriculture becomes counter cyclical in agricultural intensive economies.

Our theory has two important implications. First, it implies that as the share of the agricultural sector becomes similar across countries, business cycle properties of these countries would converge. Second, contrary to alternative stories of miss-measurement of aggregate output (e.g. Romer, 1986, 1989) and the role of stabilization policy (e.g. Burns, 1960), the role of agriculture provides a simple, measurable, and contrastable explanation in accounting for the historical properties of business cycles in the U.S. and other developed countries as documented by Backus and Kehoe (1992). Moreover, the role of agriculture may prove useful in understanding the aggregate behavior of the economy during periods of severe downturn such as the great depression in the U.S. (Cole and Ohanian, 1999).

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A Sensitivity Analysis

We evaluate the results of the benchmark economy for different values of the elasticity of substitution between agricultural and non-agricultural goods in consumption e, the weight of agricultural goods in the consumption basket a, and the properties of the stochastic process for the shocks.

Parameters pertaining to preferences of a consumption basket composed of agricultural and non-agricultural goods could not be directly restricted by micro evidence. Table 10 documents the results of the benchmark economy for different values of e, in each case re-calibrated so that all economies reported match the same targets. We evaluate values of $e \in (0, 1)$ that represent some degree of substitution across consumption goods, where low values of e imply little substitution across goods. The table shows the following implications. First, a high elasticity of substitution across goods implies that, given a stochastic process for the shocks, agricultural output and employment fluctuate more. Since the stochastic process of shocks features a small correlation of the innovations, there are large opportunities for sectoral factor reallocation. However, the reallocation of factor inputs only happens if the goods are substitutable to some degree. Second, a high substitution across goods implies a very different correlation of agricultural output and non-agricultural output, from highly positive to almost zero as e increases. Notice that the impact of e in the economy is not independent of the stochastic process of shocks. For example, a higher standard deviation of the agricultural shock would imply a smaller e needed to reproduce a given volatility of the agricultural sector.

Table 11 reports the results of the benchmark economy for different values for a. The table illustrates that the results of the benchmark economy are not sensitive to the choice of a. The reason is that, even though a affects the calibration of TFP in agriculture λ_a, the term $\lambda_a p_a$ is independent of a and this is the measure that matters for factor reallocation. The level of relative prices would provide a calibration target for a but would not affect the properties of business cycles emphasized in this paper.

In the next two tables we document the sensitivity of the benchmark results to different assumptions regarding the stochastic process for the shocks. Table 12 presents the results of the benchmark economy for different values of the correlation of the innovations of the shocks. Given the values of the benchmark calibration, the correlation of the innovations of the shocks produces a distinct pattern in the correlation of agricultural employment and non-agricultural output, ranging from -0.24 to 0.30. It also generates a wide range of volatility in agricultural output and employment. The correlation of innovations is roughly chosen to

Table 10: Sensitivity Results of Benchmark Economy to Values of e

	e								
	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90
	σ_x								
Output	1.93	1.93	1.93	1.94	1.95	1.95	1.96	1.99	2.04
Employment	1.26	1.25	1.25	1.26	1.26	1.27	1.27	1.29	1.32
Non-Ag. Employment	1.30	1.30	1.31	1.33	1.34	1.36	1.39	1.46	1.58
Ag. Employment	0.26	0.57	0.97	1.48	2.13	3.08	4.48	6.82	11.70
Ag. Output Share	1.48	1.70	2.01	2.46	3.07	3.98	5.37	7.74	12.76
Relative price	2.37	2.35	2.31	2.27	2.19	2.11	1.97	1.76	1.35
Non-Ag. Output	1.96	1.96	1.96	1.98	1.99	2.01	2.03	2.09	2.19
Ag. Output	0.74	0.87	1.15	1.58	2.19	3.10	4.47	6.82	11.78
	σ_x/σ_y								
Employment	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65
Non-Ag. Employment	0.67	0.68	0.68	0.68	0.69	0.70	0.71	0.73	0.78
Ag. Employment	0.13	0.30	0.50	0.76	1.10	1.58	2.29	3.43	5.74
Ag. Output Share	0.77	0.88	1.04	1.27	1.58	2.04	2.74	3.89	6.26
Relative price	1.23	1.22	1.20	1.17	1.13	1.08	1.01	0.88	0.66
	σ_x/σ_{y_n}								
Ag. Output	0.38	0.44	0.58	0.80	1.10	1.54	2.21	3.27	5.38
Non-Ag. Employment	0.66	0.66	0.67	0.67	0.67	0.68	0.69	0.70	0.72
Ag. Employment	0.13	0.29	0.49	0.75	1.07	1.53	2.21	3.27	5.34
	$\rho(x,y)$								
Employment	0.77	0.78	0.78	0.78	0.78	0.79	0.79	0.80	0.82
Non-Ag. Employment	0.77	0.77	0.77	0.77	0.77	0.76	0.76	0.75	0.74
Ag. Employment	−0.01	−0.02	−0.02	−0.02	−0.02	−0.03	−0.03	−0.05	−0.06
Ag. Output Share	−0.78	−0.69	−0.60	−0.50	−0.41	−0.33	−0.25	−0.20	−0.16
Relative price	−0.05	−0.03	−0.03	−0.02	−0.02	0.00	0.00	0.03	0.05
	$\rho(x,y_n)$								
Ag. Output	0.80	0.70	0.61	0.50	0.40	0.29	0.20	0.09	−0.03
Non-Ag. Employment	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.79
Ag. Employment	−0.02	−0.03	−0.03	−0.04	−0.04	−0.06	−0.07	−0.10	−0.15

Table 11: Sensitivity Results of Benchmark Economy to Values of a

	a 0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90
					σ_x				
Output	1.99	2.01	2.02	1.98	2.01	2.00	2.01	2.00	2.01
Employment	1.29	1.30	1.31	1.28	1.30	1.29	1.31	1.30	1.30
Non-Ag. Employment	1.46	1.47	1.48	1.45	1.47	1.46	1.47	1.47	1.47
Ag. Employment	6.85	6.86	6.84	6.83	6.87	6.80	6.84	6.81	6.86
Ag. Output Share	7.76	7.78	7.78	7.74	7.79	7.71	7.76	7.75	7.79
Relative price	1.76	1.77	1.76	1.76	1.77	1.75	1.76	1.75	1.77
Non-Ag. Output	2.09	2.11	2.11	2.07	2.11	2.10	2.11	2.10	2.11
Ag. Output	6.84	6.85	6.84	6.82	6.86	6.79	6.84	6.81	6.87
					σ_x/σ_y				
Employment	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65
Non-Ag. Employment	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73
Ag. Employment	3.43	3.41	3.39	3.45	3.42	3.40	3.39	3.40	3.41
Ag. Output Share	3.89	3.86	3.85	3.92	3.88	3.86	3.85	3.86	3.88
Relative price	0.88	0.88	0.87	0.89	0.88	0.87	0.87	0.88	0.88
					σ_x/σ_{y_n}				
Ag. Output	3.27	3.25	3.24	3.29	3.26	3.24	3.24	3.24	3.26
Non-Ag. Employment	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70
Ag. Employment	3.28	3.25	3.24	3.29	3.26	3.25	3.24	3.24	3.26
					$\rho(x,y)$				
Employment	0.80	0.81	0.80	0.80	0.81	0.80	0.80	0.80	0.80
Non-Ag. Employment	0.75	0.76	0.75	0.75	0.76	0.76	0.75	0.75	0.75
Ag. Employment	−0.04	−0.05	−0.05	−0.05	−0.05	−0.05	−0.04	−0.04	−0.04
Ag. Output Share	−0.19	−0.21	−0.20	−0.20	−0.21	−0.20	−0.20	−0.20	−0.20
Relative price	0.02	0.03	0.03	0.03	0.04	0.03	0.02	0.02	0.03
					$\rho(x,y_n)$				
Ag. Output	0.10	0.09	0.09	0.09	0.08	0.09	0.10	0.10	0.09
Non-Ag. Employment	0.78	0.79	0.78	0.78	0.79	0.78	0.78	0.78	0.78
Ag. Employment	−0.09	−0.11	−0.10	−0.10	−0.11	−0.10	−0.09	−0.09	−0.10

reproduce the correlation observed between agricultural employment and non-agricultural output.

Table 13 reports the results of the benchmark economy for different values of volatility of the agricultural shock. The factor k represents the proportion to which the volatility of the agricultural shock is affected where $k = 1/8$ represents the benchmark case. As expected, higher volatility of the agricultural shock would generate higher volatility of agricultural employment and output relative to the benchmark.

B Data Sources

We obtain OECD data from the following sources: National Accounts, Main Aggregates. OECD Publications; and Labour Force Statistics. OECD Publications. The sample period corresponds to 1960 to 1998. Variables used include: Y as aggregate GDP; Y_a as GDP in agriculture (including hunting, forestry and fishing); $Y_n = Y - Y_a$ as GDP in non-agriculture; L as the civilian aggregate employment; L_a as the civilian employment in agriculture (including hunting, forestry and fishing); $L_n = L - L_a$ as the employment in non-agriculture; $s_a = \frac{Y_a}{Y}$ as the agricultural share in aggregate GDP; and $\pi_a = \frac{L_a}{N}$ is the employment to working age population ratio in agriculture.

Table 12: Sensitivity Results of Benchmark Economy to Values of $\rho(\epsilon_n, \epsilon_a)$

$\rho(\epsilon_n, \epsilon_a)$	-1	$-2/3$	$-1/3$	0	1/3	2/3	1
				σ_x			
Output	2.06	2.04	2.01	2.00	1.95	1.94	1.92
Employment	1.30	1.30	1.29	1.30	1.28	1.29	1.29
Non-Ag. Employment	1.54	1.51	1.47	1.46	1.41	1.39	1.36
Ag. Employment	8.90	8.15	7.32	6.42	5.33	4.04	2.06
Ag. Output Share	9.96	9.16	8.26	7.33	6.17	4.85	3.00
Relative Price	2.29	2.10	1.88	1.65	1.37	1.04	0.54
Non-Ag. Output	2.19	2.16	2.11	2.09	2.02	1.99	1.95
Ag. Output	8.84	8.11	7.29	6.43	5.37	4.16	2.33
				σ_x/σ_y			
Employment	0.63	0.64	0.64	0.65	0.66	0.66	0.67
Non-Ag. Employment	0.75	0.74	0.74	0.73	0.72	0.72	0.71
Ag. Employment	4.32	3.99	3.65	3.22	2.73	2.09	1.07
Ag. Output Share	4.83	4.48	4.12	3.67	3.16	2.51	1.56
Relative Price	1.11	1.03	0.94	0.83	0.70	0.54	0.28
				σ_x/σ_{y_n}			
Ag. Output	4.03	3.75	3.46	3.08	2.65	2.09	1.19
Non-Ag. Employment	0.70	0.70	0.70	0.70	0.70	0.70	0.70
Ag. Employment	4.05	3.77	3.47	3.08	2.63	2.03	1.05
				$\rho(x, y)$			
Employment	0.80	0.80	0.80	0.80	0.80	0.80	0.80
Non-Ag. Employment	0.75	0.75	0.75	0.75	0.75	0.75	0.76
Ag. Employment	-0.18	-0.13	-0.08	-0.01	0.06	0.18	0.33
Ag. Output Share	-0.29	-0.25	-0.22	-0.18	-0.13	-0.06	0.01
Relative Price	0.16	0.11	0.06	-0.01	-0.08	-0.20	-0.35
				$\rho(x, y_n)$			
Ag. Output	-0.06	0.00	0.06	0.13	0.21	0.33	0.48
Non-Ag. Employment	0.79	0.78	0.78	0.78	0.78	0.78	0.78
Ag. Employment	-0.24	-0.18	-0.13	-0.07	0.01	0.14	0.30

Table 13: Sensitivity Results of Benchmark Economy to Values of k

k	1/8	1/2	1	2	8
			σ_x		
Output	2.00	2.05	2.21	2.71	8.72
Employment	1.29	1.34	1.49	2.00	6.25
Non-Ag. Employment	1.46	1.53	1.68	2.15	6.04
Ag. Employment	6.80	16.20	36.20	103.52	168.44
Ag. Output Share	7.72	16.56	34.62	85.11	145.25
Relative price	1.75	4.13	8.78	21.58	37.96
Ag. Output	2.09	2.18	2.38	2.97	8.09
Ag. Output	6.79	16.08	34.38	85.20	148.04
			σ_x/σ_y		
Employment	0.65	0.65	0.67	0.74	0.72
Non-Ag. Employment	0.73	0.74	0.76	0.79	0.69
Ag. Employment	3.41	7.89	16.38	38.18	19.32
Ag. Output Share	3.87	8.06	15.66	31.39	16.66
Relative price	0.88	2.01	3.97	7.96	4.35
			σ_x/σ_{y_n}		
Ag. Output	3.25	7.39	14.46	28.71	18.30
Non-Ag. Employment	0.70	0.70	0.71	0.72	0.75
Ag. Employment	3.25	7.44	15.22	34.89	20.82
			$\rho(x,y)$		
Employment	0.80	0.79	0.78	0.76	0.71
Non-Ag. Employment	0.76	0.74	0.73	0.69	0.53
Ag. Employment	−0.05	−0.06	−0.07	−0.05	0.10
Ag. Output Share	−0.21	−0.14	−0.12	−0.07	0.20
Relative price	0.03	0.05	0.06	0.02	−0.12
			$\rho(x,y_n)$		
Ag. Output	0.09	−0.05	−0.16	−0.26	−0.29
Non-Ag. Employment	0.78	0.78	0.79	0.79	0.80
Ag. Employment	−0.10	−0.16	−0.23	−0.30	−0.39

Table 14: Cross-Country Business Cycle Fluctuations

	Average		Standard Deviation σ_x										
Country	s_a	π_a	Y	Y_n	Y_a	L	L_n	L_a	s_a	π_a	Y/L	Y_n/L_n	Y_a/L_a
U.S.	0.02	0.02	2.12	2.16	5.48	1.34	1.39	2.28	5.81	2.25	1.28	1.28	5.75
Canada	0.03	0.04	2.20	2.27	4.11	1.75	1.83	2.19	4.75	2.44	1.91	1.93	4.57
Australia	0.04	0.04	2.07	2.15	7.33	1.91	1.97	2.47	7.51	2.35	1.46	1.40	8.23
Japan	0.04	0.07	2.19	2.24	4.26	0.78	0.94	2.33	4.20	2.38	1.76	1.67	5.18
Austria	0.03	0.06	1.51	1.58	3.09	0.83	0.82	2.94	3.53	2.87	1.83	1.83	3.66
Belgium	0.02	0.02	1.81	1.88	3.84	1.07	1.12	1.32	4.82	1.29	1.22	1.24	4.06
Denmark	0.04	0.06	1.85	2.12	11.95	1.90	2.13	3.62	12.83	3.53	1.46	1.56	12.46
Finland	0.07	0.09	3.81	4.01	5.21	3.06	3.29	3.97	5.65	3.98	2.21	1.91	5.31
France	0.05	0.05	1.80	1.83	4.27	0.96	1.14	1.42	4.11	1.39	1.21	1.14	4.50
Greece	0.13	0.18	2.27	2.66	4.58	1.05	0.91	2.71	4.81	2.63	2.83	2.64	5.32
Italy	0.04	0.07	1.85	1.95	2.83	1.23	1.32	2.26	3.61	2.31	1.83	1.90	3.13
Luxembourg	0.03	0.04	3.39	3.48	4.61	1.94	2.00	4.33	5.42	4.02	2.97	3.01	7.25
Netherlands	0.03	0.03	2.14	2.22	3.31	1.24	1.33	1.38	4.15	1.41	2.21	2.29	3.42
Norway	0.03	0.06	1.94	2.05	4.71	1.94	1.95	3.69	5.38	3.67	1.44	1.43	6.11
Portugal*	0.07	0.17	3.22	3.45	6.44	1.60	2.30	2.81	7.03	2.69	3.03	3.23	6.63
Spain	0.06	0.07	2.31	2.37	5.77	3.29	3.89	2.70	5.46	2.75	1.25	1.73	5.50
Sweden	0.02	0.04	1.93	1.95	4.63	1.63	1.85	3.11	4.46	3.11	1.45	1.36	5.33
Turkey	0.19	0.30	3.25	3.72	2.55	0.75	1.54	2.14	2.72	2.28	3.24	3.28	3.75
Average	0.05	0.08	2.31	2.45	4.94	1.57	1.76	2.65	5.35	2.63	1.92	1.94	5.56

* Data is only from 1974 to 1991.

Table 15: Cross-Country Business Cycle Correlations

	Correlation with aggregate output $\rho(x, Y)$									
Country	Y_n	Y_a	L	L_n	L_a	s_a	π_a	Y/L	Y_n/L_n	Y_a/L_a
U.S.	1.00	0.03	0.82	0.83	-0.14	-0.33	-0.13	0.80	0.79	0.09
Canada	1.00	-0.05	0.56	0.57	-0.13	-0.50	0.06	0.65	0.63	0.02
Australia	0.99	0.05	0.73	0.74	0.30	-0.22	0.21	0.46	0.48	-0.04
Japan	1.00	0.28	0.68	0.74	-0.09	-0.24	-0.16	0.94	0.92	0.27
Austria	1.00	-0.07	-0.14	-0.05	-0.30	-0.49	-0.22	0.98	0.89	0.18
Belgium	1.00	-0.38	0.76	0.77	-0.36	-0.67	-0.24	0.82	0.81	-0.24
Denmark	0.98	-0.42	0.70	0.75	-0.43	-0.53	-0.45	0.36	0.31	-0.27
Finland	1.00	0.25	0.82	0.87	-0.05	-0.45	-0.04	0.59	0.58	0.28
France	0.99	0.30	0.78	0.81	-0.44	-0.13	-0.34	0.87	0.79	0.42
Greece	0.96	0.15	-0.36	0.22	-0.49	-0.33	-0.42	0.94	0.89	0.38
Italy	1.00	-0.15	0.35	0.39	0.03	-0.63	0.08	0.78	0.75	-0.16
Luxembourg	1.00	0.11	0.49	0.51	0.08	-0.54	0.03	0.82	0.82	0.02
Netherlands	1.00	-0.12	0.23	0.26	-0.28	-0.61	-0.23	0.84	0.82	0.00
Norway	1.00	-0.17	0.72	0.74	0.31	-0.51	0.32	0.37	0.42	-0.32
Portugal*	0.99	0.06	0.36	0.41	-0.23	-0.40	0.01	0.87	0.77	0.15
Spain	0.99	0.33	0.96	0.96	0.04	-0.08	0.06	-0.67	-0.80	0.32
Sweden	1.00	0.30	0.69	0.74	-0.63	-0.12	-0.62	0.51	0.43	0.63
Turkey	0.99	0.58	0.13	0.49	-0.27	-0.65	-0.24	0.97	0.89	0.55
Average	0.99	0.06	0.52	0.60	−0.17	−0.41	−0.33	0.66	0.62	0.13

* Data is only from 1974 to 1991.

Table 16: Other Cross-Country Business Cycle Facts

	σ_x/σ_Y					$\rho(x, Y_n)$					
Country	Y_n	Y_a	L	L_n	L_a	Y_a	L	L_n	L_a	s_a	π_a
U.S.	1.02	2.58	0.63	0.66	1.08	-0.01	0.82	0.83	-0.14	-0.37	-0.13
Canada	1.03	1.87	0.80	0.83	1.00	-0.10	0.55	0.57	-0.13	-0.55	0.06
Australia	1.04	3.54	0.92	0.95	1.19	-0.07	0.77	0.77	0.33	-0.35	0.24
Japan	1.02	1.95	0.36	0.43	1.06	0.21	0.69	0.74	-0.07	-0.30	-0.14
Austria	1.05	2.05	0.55	0.54	1.95	-0.14	-0.16	-0.06	-0.32	-0.55	-0.24
Belgium	1.04	2.12	0.59	0.62	0.73	-0.41	0.75	0.77	-0.36	-0.70	-0.23
Denmark	1.15	6.46	1.03	1.15	1.96	-0.57	0.68	0.73	-0.41	-0.68	-0.42
Finland	1.05	1.37	0.80	0.86	1.04	0.15	0.81	0.88	-0.09	-0.53	-0.09
France	1.02	2.37	0.53	0.63	0.79	0.19	0.78	0.80	-0.45	-0.24	-0.35
Greece	1.17	2.02	0.46	0.40	1.19	-0.12	-0.39	0.19	-0.50	-0.57	-0.43
Italy	1.05	1.53	0.66	0.71	1.22	-0.21	0.34	0.38	0.02	-0.68	0.06
Luxembourg	1.03	1.36	0.57	0.59	1.28	0.07	0.49	0.50	0.09	-0.56	0.04
Netherlands	1.04	1.55	0.58	0.62	0.64	-0.17	0.22	0.25	-0.29	-0.65	-0.23
Norway	1.06	2.43	1.00	1.01	1.90	-0.24	0.73	0.75	0.31	-0.57	0.32
Portugal*	1.07	2.00	0.5	0.71	0.87	-0.07	0.37	0.43	-0.25	-0.52	-0.03
Spain	1.03	2.50	1.42	1.68	1.17	0.21	0.96	0.96	0.00	-0.20	0.01
Sweden	1.01	2.40	0.84	0.96	1.61	0.24	0.70	0.75	-0.65	-0.18	-0.63
Turkey	1.14	0.78	0.23	0.47	0.66	0.47	0.14	0.47	-0.25	-0.75	-0.23
Average	1.06	2.27	0.69	0.77	1.19	-0.03	0.51	0.60	-0.18	-0.50	-0.13

* Data is only from 1974 to 1991.