Essays in the Study of Aggregate Fluctuations

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THESIS

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Abstract

This thesis consists of three self-contained papers on business cycle fluctuations in the context of the dynamic stochastic general equilibrium framework.

The first paper examines how maintenance expenditures affect the occurrence of indeterminacy in a two-sector model economy, motivated by the empirical fact that equipment and structures are maintained and repaired. McGrattan and Schmitz's (1999) survey on 'Capital and Repair Expenditures' in Canada indicates that maintenance expenditures account for a substantial fraction of output and new investment. It is shown that the endogenous maintenance expenditures reduce the requirement of the degree of increasing returns to scale to generate sunspot equilibria. In fact, the minimum level of the returns to scale required could be as low as 1.0179. This aspect is important since empirical works such as Basu and Fernald (1997) suggests that returns to scale is close to constant.

The second paper addresses the following questions in the context of a neoclassical model of the business cycle: what caused the 1890s and 1907 recessions in the U.S.? In particular, we apply the Business Cycle Accounting method to decompose the economic fluctuation into its sources: productivity, the labour wedge, the investment wedge and the government consumption wedge. Our results suggest that the economy downturn is primarily attributed to frictions that reduce productivity and the wedge capturing distortions in labour-leisure decision. The financial market frictions would have accounted for the drop of the efficiency wedge. A contractionary monetary shock could generate a gap between the marginal rate of substitution and the marginal product of labour.

The third paper applies the accounting method proposed by Chari, Kehoe and McGrattan (2007) to identify the primary sources of economic slumps in South Australia from 1990 to 2014. We focus on three major stages: the recession in the early-1990s, the Asian Financial Crisis and the 2008-2012 South Australian slump. Our results show that the efficiency wedge is the primary transmission channel through which the primitive shocks hit the South Australian economy. Shocks such as structural transformation, collapse of motor vehicle industry might have affected the efficiency wedge. Moreover, it is illustrated that infrastructural expenditures are important in increasing the efficiency wedge. This is conformity with the fact that South Australian government is keen to support its development through the Economic Stimulus Plan. Trade openness might also be a contributor.

Declaration

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Chapter 1

Introduction

The aim of this thesis is to contribute to the understanding of business cycles based on dynamic stochastic general equilibrium models. This thesis consists of three independent parts involving two streams of business cycle theories: the sunspot-driven indeterminacy model and the neoclassical model incorporating various types of frictions.

An extensive macroeconomic literature such as Benhabib and Farmer (1996), Wen (1998), Harrison and Weder (2002), to name just a few, demonstrate that indeterminacy can arise due to some degree of increasing returns to scale technologies, often exhibited via external effects. Empirical findings by Basu and Fernald (1997) that the presence of production externalities is modest triggered researchers' interest in pursuing model structures with lower scale economies to generate indeterminacy.

The first paper works on such a model. It examines how maintenance expenditures affect the occurrence of indeterminacy in a two-sector model economy. In this model, indeterminacy arises due to the sector-specific externalities. The main feature of this model is that the capital depreciation rate varies with capital utilization rate and maintenance expenditures, whereas in many other related two-sector model papers the evolution of the depreciation rate is solely determined by variable capital utilization. Empirical studies such as McGrattan and Schmitz's (1999) survey on 'Capital and Repair Expenditures' in Canada show that maintenance expenditures account for a non-ignorable proportion of output and new investment, indicating that such expenditure is 'too big to ignore'. In the model, the amount of maintenance expenditures affects the capital accumulation law and is upon the representative agent's optimal decisions.

The results show that the minimum level of returns to scale could be as low as 1.0179 to obtain indeterminacy. Intuitively, if an agent expects that the rate of return on capital will be higher tomorrow, he/she responds by increasing tomorrow's capital stock. In the presence of maintenance activities, the existing capital becomes more productive and the marginal product of capital increases. Therefore, a milder degree of externalities is required than the economy where there is no maintenance expenditures for the agent's expectation to be self-fulfilling. The simulated model generates two counterfactual behaviours: (i) consumption and real wage are countercyclical, (ii) investment is much too volatile. Overall the model performs reasonably well. This paper also considers a model variant in which capital utilization is assumed to be constant over time. The result that indeterminancy is easier to obtain in models with maintenance activities than non-maintenance economic variants is robust. Under this formation, the countercyclical consumption puzzle is solved and most features of the model moments are comparable to the U.S. data.

The second paper asks: what caused the depression of the 1890s and the 1907 recessions in the U.S.? It is imperative to explore the economic fluctuations during this period since it is simpler in important respects. During the National Banking Era, there were no reliable Central Bank or government policies that could intervene in the economy. Therefore we can concentrate our analysis on the sources of shocks that instigate a downturn instead of policy responses that may have deepened the economic contractions.

As there are many possible causes of economic fluctuations, it is often hard to choose which frictions are the most explanatory ones. We use the Business Cycle Accounting technique to decompose output, labour, investment and consumption into fluctuations due to the efficiency wedge, labour wedge, investment wedge and government consumption wedge. These wedges measure the deviations of the real world economic data from its best outcome implied by the standard growth model. Literally, these four wedges are the total factor productivity shock, the labour and investment tax, government spending plus net export. The analyses are in the context of a neoclassical model of the business cycle. Then we evaluate the relative importance of these wedges to the development of the macroeconomic variables and identify the primary ones.

Our results suggest that the economy downturns are primarily attributed to frictions that reduce productivity and the wedge capturing distortions in labour-leisure decision. We also identify the frictions that might affect the economy through these wedges. Firstly, variable capital utilization could be an important determinant of the efficiency wedge. Besides that, we explore the frictions that could manifest themselves as the efficiency wedge. We find that financial sector difficulties, might be induced by large business failures, could have been the factor deteriorating the efficiency wedge during the recessions. Secondly, a contractionary monetary shock could generate a gap between the marginal rate of substitution and the marginal product of labour.

The third paper analyzes the sources of the fluctuations in the South Australian economy from 1990 to 2014 using the same accounting procedure as the second paper. We focus on three major stages: the recession in early-1990s, the Asian Financial Crisis and the 2008-2012 South Australian economic slump. Our results show that the efficiency wedge, measured as the total factor productivity, is the primary transmission channel through which the primitive shocks hit the South Australian economy. In the next step we elabourate on factors that might affect the efficiency wedge, including structural transformation and the collapse of automotive industry. Moreover, public infrastructure provision and trade openness are also productivity engines. In comparison with other states of Australia, South Australian infrastructure investment to output ratio and the trade openness index are both overall subdued and its economic growth is also lagged behind other states.

Chapter 2

Indeterminacy, Capital Maintenance Expenditures and the Business Cycle

2.1 Introduction

Recent years have witnessed the formulation of business cycle models with multiple equilibria. In particular, many researchers explore the mechanisms that give rise to indeterminacy.[1] It has been recognized that the indeterminacy could arise if the assumption of a perfect market is relaxed. In earlier research such as Benhabib and Farmer (1994), the existence of a continuum of equilibria relies on a high degree of increasing returns to scale in production. However, empirical work by Basu and Fernald (1997) depicts that the presence of production externalities is rather modest, if any, which led researchers to pursue model structures with lower scale economies to induce indeterminacy. The increasing returns to scale are often exhibited via external effects.

[1] Examples include Benhabib and Farmer, 1996; Wen, 1998; Guo and Harrison, 2001; Harrison and Weder, 2000.

This paper works on such a model. Specifically, we examine a two-sector model in which production takes place in both consumption and investment sectors. Indeterminacy arises due to the sector-specific externalities. The external effects in one sector only depend on the aggregate production of its own sector. The technologies in two sectors are assumed to have the same form, except that the scaling factors representing the external effects differ across sectors. A main feature of this model is that the capital depreciation rate varies with capital utilization rate and maintenance expenditures. McGrattan and Schmitz (1999) define maintenance expenditures as "the expenditures made for the purpose of keeping the stock of fixed assets or productive capacity in good working order during the life originally intended". Licandro and Puch (2000) point out that such expenditures are important factors affecting depreciation, as machines are better preserved if maintenance activity is engaged during the production process. In most indeterminacy literature, the capital depreciation rate is assumed to be exogenous and constant over time, or is assumed to vary with capital utilization rate alone. In this research we focus on the role of maintenance expenditures in generating multiple equilibria in an artificial economy. It will be shown that our model economy is able to generate indeterminacy at rather mild degree of market imperfections.

Empirical studies affirm the importance of maintenance expenditures. McGrattan and Schmitz (1999) conduct a survey on 'Capital and Repair Expenditures' in Canada and show that expenditures on maintenance activity are large relative to that on other activities. In this survey, total maintenance and repair expenditures accounted for 5.7 percent of gross domestic product (GDP) over 1981-1993.[2] Over the same period, these expenditures averaged about 28 percent of spending on new investment. Expenditures on R&D were 1.4 percent of GDP which was much lower than maintenance-to-GDP ratio. Moreover, the proportion of public spending on education was 6.8 percent which

[2]It accounted for 6.1 percent of GDP if the period covers from 1961 to 1993.

was only slightly higher than that of maintenance expenditures, indicating that maintenance expenditures are 'too big to ignore'.

In our two-sector model we allow agents to allocate resources to maintenance activities, that is, such expenditures also affect the capital accumulation process. Our model relates to Guo and Lansing (2007). They investigate the indeterminancy properties of a one-sector model with maintenance expenditures. As there is a lack of data on maintenance expenditures in the U.S., they calibrate maintenance-to-GDP ratio using Canadian data as the proxy for U.S. data. In this paper we consider a two-sector case as subsequent research has indicated that models with two-sector or multi-sectors of production require much lower increasing returns to obtain indeterminacy.[3] Furthermore, we allow households to make decisions on capital maintenance expenditure as households own the capital, whereas in Guo and Lansing's (2007) economy the sequence of maintenance expenditures is the firms' choice. Our results show that the minimum level of returns to scale necessary for indeterminacy is 1.0179 which is close to constant.

It has been criticized that a model combining both two production sectors and variable capital utilization tends to generate an extremely narrow range of increasing returns that give rise to indeterminacy (Guo & Lansing 2007). Under this circumstance it is not possible to generate pro-cyclical consumption with such low degree of externalities. Therefore, we also display a two-sector model with constant utilization which is in fact an extension of Benhabib and Farmer's (1996) model by incorporating maintenance activities. We are able to solve the consumption-cyclicity puzzle if the size of increasing returns is sufficiently large.

The role of maintenance expenditures on the occurrence of indeterminacy is obvious. Suppose that agents become optimistic about the future; for example, they expect a

[3] For example, Benhabib and Farmer (1996), Harrison (1996), Weder (2000).

higher rate of return on capital. In response to this expectation, they increase investment goods expenditure. Labour flows from the consumption goods sector into the investment goods sector, increasing the production of investment goods and therefore increasing future capital stock. With sufficient increasing returns to scale, the increase in capital stocks is associated with a higher rate of return, and the agents' expectation can be self-fulfilling. Involving maintenance activities reduces the required level of increasing returns to scale as it makes the existing capital like machines more productive than unmaintained ones, which tends to increase the marginal product of capital and therefore the net return on capital.

The rest of this paper is organized as follows. Section 2.2 presents the model. Section 2.3 analyzes the local dynamics and the indeterminacy properties. We also provide discussion about maintenance expenditures and indeterminacy. In section 2.4 we show the business cycle properties generated from the models and address the cyclicality of consumption issue. Section 2.5 concludes.

2.2 The Model

The model incorporates maintenance expenditures into Guo and Harrison's (2001) two-sector model. The economy consists of a continuum of identical households who make decisions about consumption, labour hours worked, utilization rate of capital and maintenance expenditures. Households own the capital and lend capital and labour services to firms, taking rent and real wage rate as given. Firms produce consumption and investment goods which are sold to households. Households own the firms and therefore the profits are remitted to households.

2.2.1 Preferences and Household's Choices

A representative household chooses the sequences of consumption C_t and hours worked L_t to maximize his lifetime utility

$$\int_0^\infty (lnC_t - \frac{L_t^{1+\chi}}{1+\chi})e^{-\rho t}dt,$$

where χ captures the inverse elasticity of labour supply and ρ is the discount rate. The budget constraint faced by the household is

$$C_t + P_t I_t = r_t u_t K_t + w_t L_t,$$

where I_t is the household's investment in new capital, P_t is the relative price of investment goods in units of consumption goods. r_t and w_t are the rental rate of capital and the real wage rate, respectively. u_t is the rate of capital utilization. Let K_t denotes economy-wide capital stock. The law of motion for capital accumulation is given by

$$\dot{K}_t = I_t - \delta_t K_t - M_t,$$

where M_t is goods expenditure on maintenance. $\delta_t \in (0, 1)$ is the rate of capital depreciation which is variable over time. Following Guo and Lansing (2007), δ_t has the form of

$$\delta_t = \tau \frac{u_t^\theta}{(M_t/K_t)^\phi},$$

where $\tau > 0$, $\theta > 1$,and $\phi \geq 0$. θ is the elasticity of depreciation with respect to capital utilization. ϕ captures the elasticity of depreciation rate with respect to maintenance cost rate:

$$\phi = -\frac{\partial \delta_t}{\partial (M_t/K_t)} \times \frac{(M_t/K_t)}{\delta_t}.$$

Licandro and Puch (2000) define M_t/K_t as 'the maintenance cost rate' that captures the intensity of maintenance activities. Above form of the depreciation rate implies that the depreciation rate depends on both capital utilization and maintenance activities. Higher capital utilization rate accelerates the depreciation whereas higher maintenance expenditures has the opposite effect (Guo and Lansing, 2007).

Let Λ_t be the co-state variable associated with the Hamiltonian set-up of the household's optimization problem. It is often explained as the shadow price of capital, meaning the marginal utility gain if agent's capital constraint is relaxed. Then the first-order conditions are given by

$$\frac{1}{C_t} = \Lambda_t P_t^{-1}, \tag{2.1}$$

$$\Lambda_t w_t P_t^{-1} = L_t^{\chi}, \tag{2.2}$$

$$r_t P_t^{-1} u_t = \theta \delta_t, \tag{2.3}$$

$$\phi \delta_t \frac{K_t}{M_t} = 1, \tag{2.4}$$

$$\frac{\dot{\Lambda}_t}{\Lambda_t} = \rho - r_t u_t P_t^{-1} + (\phi + 1)\delta_t. \tag{2.5}$$

The transversality condition is $\lim_{t \to \infty} e^{-\rho t} \Lambda_t K_t = 0$. Equations (2.1) and (2.2) show the intratemporal trade-off between consumption and leisure. Equation (2.3) shows that the household utilizes capital by equating the marginal gain and marginal loss of a change in utilization rate. Equation (2.4) indicates that the household equates one unit of good expenditure on maintenance to marginal maintenance cost rate with respect to the depreciation rate. Equation (2.5) is the intertemporal Euler equation.

2.2.2 Production Technology

The production functions for the consumption sector and investment sector are given by

$$Y_{ct} = A_t(u_t K_{ct})^{\alpha} L_{ct}^{1-\alpha},$$

where $A_t = [(\bar{u}_t \bar{K}_{ct})^{\alpha} \bar{L}_{ct}^{1-\alpha}]^{\eta}$ and

$$Y_{xt} = B_t(u_t K_{xt})^{\alpha} L_{xt}^{1-\alpha},$$

where $B_t = [(\bar{u}_t \bar{K}_{xt})^{\alpha} \bar{L}_{xt}^{1-\alpha}]^{\eta}$.

Y_{ct} and Y_{xt} denote the production of consumption goods and investment goods. K_{it} and L_{it} are the capital and labour inputs used in the production of sector i for $i = C, I$. α is the capital share in each sector. A_t and B_t are scaling factors that capture the external effects. A bar over variables means the economy-wide average which firms taken as given. η captures the degree of sector-specific externalities[4] and is assumed to be non-decreasing, $\eta > 0$.

Under the assumption that the factor markets are perfectly competitive, the first-order conditions for the representative firm are

[4]The sizes of the externalities in the consumption and investment sectors are assumed to be the same. Harrison (2001) points out that if the utility function is logarithmic in consumption then the indeterminancy properties are independent of the degree of the externalities in the consumption sector.

$$u_t r_t = \frac{\alpha Y_{ct}}{K_{ct}} = P_t \frac{\alpha Y_{xt}}{K_{xt}}, \tag{2.6}$$

$$w_t = \frac{(1-\alpha)Y_{ct}}{L_{ct}} = P_t \frac{(1-\alpha)Y_{xt}}{L_{xt}}. \tag{2.7}$$

2.3 Equilibrium and Local Dynamics

We focus on perfect foresight equilibrium which is defined as a path $\{K_t,\, L_t,\, M_t,\, u_t,\, \Lambda_t$ $,\, s_t,\, C_t\,\}_{t=0}^{\infty}$ and a set of prices $\{P_t,\, r_t,\, w_t\}_{t=0}^{\infty}$ satisfying household and firm's first-order conditions and their resource constraints. Let s_t be the ratio of the aggregate capital and labour used in the consumption sector,

$$s_t = \frac{K_{ct}}{K_t} = \frac{L_{ct}}{L_t}.$$

In equilibrium, the consistency requires that

$$u_t = \bar{u}_t, K_{ct} = \bar{K}_{ct}, L_{ct} = \bar{L}_{ct}, K_{xt} = \bar{K}_{xt}, L_{xt} = \bar{L}_{xt}.$$

As capital and labour are only used in the production of consumption and investment goods, the following conditions must be satisfied:

$$K_{ct} + K_{xt} = K_t, L_{ct} + L_{xt} = L_t.$$

And as total production consists of consumption and investment goods, we must have

$$Y_t = Y_{ct} + P_t Y_{xt},$$

where Y_t denotes the aggregate output produced in the economy.

Then we can derive the following production functions:

$$Y_{ct} = s_t^{1+\eta}(u_t K_t)^{\alpha(1+\eta)} L_t^{(1-\alpha)(1+\eta)}, \quad (2.8)$$

$$Y_{xt} = (1-s_t)^{1+\eta}(u_t K_t)^{\alpha(1+\eta)} L_t^{(1-\alpha)(1+\eta)}, \quad (2.9)$$

$$Y_t = s_t^{\eta}(u_t K_t)^{\alpha(1+\eta)} L_t^{(1-\alpha)(1+\eta)}, \quad (2.10)$$

We assume that $\alpha(1+\eta) < 1$, implying moderate size of increasing returns so that it is not able to generate endogenous growth.

The consumption and investment goods demanded by household and supplied by firms are equal, implying

$$C_t = Y_{ct}, I_t = Y_{xt}.$$

From equations (2.6) and (2.7) we can get the factor prices and the relative price of investment good in terms of consumption goods

$$u_t r_t = \alpha s_t^{\eta} \frac{(u_t K_t)^{\alpha(1+\eta)} L_t^{(1-\alpha)(1+\eta)}}{K_t}, \quad (2.11)$$

$$w_t = (1-\alpha) s_t^{\eta} \frac{(u_t K_t)^{\alpha(1+\eta)} L_t^{(1-\alpha)(1+\eta)}}{L_t}, \quad (2.12)$$

$$P_t = (\frac{s_t}{1-s_t})^{\eta}. \quad (2.13)$$

We can get the reduced form of the production function, we use equation (2.3), (2.4) and (2.11) to derive the expression for optimal capital utilization in terms of aggregate capital and labour and then substitute it into equation (2.10).[5] The reduced form of aggregate production function is given by

$$Y_t = D_t K_t^{\frac{\alpha(1+\eta)(\theta-\phi-1)}{\theta-\alpha(1+\eta)(\phi+1)}} L_t^{\frac{(1-\alpha)(1+\eta)\theta}{\theta-\alpha(1+\eta)(\phi+1)}},$$

where D_t is an expression in terms of parameters and s_t, the fraction that the aggregate capital and labour used in the consumption sector. The variable utilization rate changes the production function and induces Wen's (1998) so-called 'return-to-scale effect' as

$$\frac{\alpha(1+\eta)(\theta-\phi-1)}{\theta-\alpha(1+\eta)(\phi+1)} + \frac{(1-\alpha)(1+\eta)\theta}{\theta-\alpha(1+\eta)(\phi+1)} > 1+\eta.$$

The output elasticity with respect to capital and labour coincide with Guo and Lansing (2007). We restrict our analysis by $0 < \frac{\alpha(1+\eta)(\theta-\phi-1)}{\theta-\alpha(1+\eta)(\phi+1)} < 1$ to ensure that the positive externalities exhibits and that there is no endogenous growth, implying that $\theta-\phi-1 > 0$.

We analyze the properties of local dynamics of the model by taking log-linear approximations around the steady state. Then dynamic system becomes

$$\begin{bmatrix} \dot{log}\Lambda_t \\ \dot{log}K_t \end{bmatrix} = J \begin{bmatrix} log\Lambda_t - log\Lambda \\ logK_t - logK \end{bmatrix}.$$

The variables without time subscript refer to their steady state level and J is a 2×2 Jacobian matrix. Λ_t is a non-predetermined variable and K_t is a pre-determined variable. Indeterminacy requires that both eigenvalues of the Jacobian matrix J are negative. Since the trace of J measures the sum of the roots and the determinant measures the product of them, indeterminacy requires that $TrJ < 0 < DetJ$. When

[5]For simplicity, τ is set to equal $\frac{1}{\theta}$ as it does not play any role in the model's steady state and indeterminacy properties.

indeterminacy arises, equilibria may be driven by sunspots.

2.3.1 The One-sector Model

In this subsection we first consider the case where there are no sector-specific externalities, instead we allow for the aggregate externalities, denoted by γ. Hence, $\alpha(1+\gamma) < 1$. The model is reduced to a one-sector model that corresponds to the continuous time version of Guo and Lansing's (2007) model , implying $P_t = 1$. Firm maximizes its profit subject to the following production function:

$$Y_t = A_t(u_t K_t)^{\alpha} L_t^{1-\alpha},$$

where $A_t = [(\overline{u}_t \overline{K}_t)^{\alpha} \overline{L}_t^{1-\alpha}]^{\gamma}$.

In the following analysis we focus on the case of $\chi = 0$, a standard assumption in real business cycle models, implying infinite labour supply elasticity or indivisible labour. The household's utility function becomes

$$\int_0^{\infty} (lnC_t - L_t) e^{-\rho t} dt,$$

which is essentially the Hansen-Rogerson preference.

Then the determinant of J is given by

$$DetJ = \frac{[\alpha(1+\gamma) - 1]\theta\rho^2(\theta - \alpha\phi - \alpha)}{\alpha[-\gamma\theta + \alpha(1+\gamma)(\theta - \phi - 1)](\theta - \phi - 1)},$$

and the trace of the matrix is

$$TrJ = \frac{\alpha(1+\gamma)\rho(\theta-\phi-1)}{-\gamma\theta+\alpha(1+\gamma)(\theta-\phi-1)}.$$

The necessary and sufficient conditions for indeterminacy requires negative trace and positive determinant. As $\alpha(1+\gamma)-1 < 0$ and $\theta-\phi-1 > 0$, the determinant is always positive when $-\gamma\theta+\alpha(1+\gamma)(\theta-\phi-1) < 0$. Trace is always negative when this condition is satisfied. This implies proposition 1.

Proposition 1. *In the one-sector model with endogenous maintenance activities and variable capital utilization, indeterminacy arises if and only if the degree of aggregate externalities satisfies*

$$\frac{\alpha(\theta-\phi-1)}{\theta-\alpha(\theta-\phi-1)} < \gamma < \frac{1}{\alpha} - 1.$$

We quantitatively investigate the local dynamic properties using Benhabib and Farmer's (1996) model calibration. The capital share, α, equals 0.3, implying that the labour share $1-\alpha$ is 0.7, the depreciation rate δ is 0.1, the discount value ρ equals 0.05. The values of θ and ϕ depend on the maintenance cost rate M/K and the maintenance-to-GDP ratio M/Y. From the household and firm's first-order conditions together with the equilibrium conditions we can obtain that

$$\frac{M}{K} = \frac{\phi\rho}{\theta-\phi-1},$$

$$\frac{M}{Y} = \frac{\alpha\phi\delta(\theta-\phi-1)}{\rho\theta}.$$

In equilibrium both the maintenance cost rate and the maintenance-to-GDP ratio are positive constants and depend on parameter values only, implying that maintenance expenditures are procyclical to capital and output. Following Guo and Lansing (2007), we use Canada's data estimated by McGrattan and Schmitz (1999) as the proxy of the steady state maintenance-to-GDP ratio (ranged between 5.7 percent and 6.1 percent). Here we set $M/Y = 0.061$, implying that the value of θ and ϕ are 1.8828 and 0.3828, respectively. Given these parameter values, the model requires $\gamma_{min} = 0.0866$ for the steady state to be indeterminate.

When the economy is in the absence of maintenance activities, meaning that $\phi = 0$ and $M = 0$, the minimum degree of externalities required for indeterminacy is 0.1111 which is higher than the case involving maintenance activities. The results quantitatively imply that a positive equilibrium ratio of maintenance costs leads to lower minimum required degree of increasing returns, which is consistent with Guo and Lansing's (2007) discrete time version of the one-sector model.

2.3.2 The Two-sector Models

In this subsection, we discuss the indeterminacy properties of two-sector models. We assume that the capital utilization rate is the result of household's optimal decisions. We are able to show that under this model formulation, to our knowledge the minimum level of increasing returns to scale, or externalities, required is the smallest among its model predecessors.

However, Guo and Lansing (2007) point out that a model combining both production sectors and endogenous capital utilization will generate an extremely narrow range of increasing returns that give rise to multiple equilibria. As the upper bound of the required degree of externalities in this model is very small, it is likely that the time series data generated in this model have some properties that are counterfactual. Notably, it is not possible to get pro-cyclical consumption with such low degree of externalities when the model displays indeterminacy.

Therefore we also show an alternative two-sector model with maintenance expenditures. In this model, the capital utilization is assumed to be fixed, that is, $u_t = u$. We provide an extension of Benhabib and Farmer's (1996) model by including endogenous maintenance activities. Under this model setup we are able to get procyclical consumption and reasonable values of other moments when the degree of externalities is sufficiently large. It is clear that maintenance expenditures still play an important role in generating indeterminacy.

2.3.2.1 Endogenous Capital Utilization

First we consider a two-sector model with sector-specific externalities. Then the trace and determinant of J are given by

$$TrJ = \frac{\rho[-\eta\theta^2 + \alpha\eta\theta(1+\phi) + \alpha^2(1+\eta)(\theta-\phi-1)(1+\phi)]}{-\eta\theta^2 + \alpha^2(1+\eta)(\theta-\phi-1)(1+\phi)},$$

$$DetJ = \frac{-[\alpha(1+\eta)-1]\theta\rho^2(1+\phi)(\theta-\alpha\phi-\alpha)}{(\theta-\phi-1)[\eta\theta^2 - \alpha^2(1+\eta)(\theta-\phi-1)(1+\phi)]}.$$

Under the assumption of $\alpha(1+\eta) < 1$ and $\theta - \phi - 1 > 0$, the determinant is always positive when $\eta\theta^2 - \alpha^2(1+\eta)(\theta-\phi-1)(1+\phi) > 0$. The trace is negative if $-\eta\theta^2 + \alpha\eta\theta(1+\phi) + \alpha^2(1+\eta)(\theta-\phi-1)(1+\phi) > 0$. These inequalities translate into the following proposition:

Proposition 2. *In the two-sector model with endogenous maintenance activities and capital utilization, when* $\theta^2 - \alpha\theta(1+\phi) - \alpha^2(\theta-\phi-1)(1+\phi) > 0$*, indeterminacy arises if and only if*

$$\frac{\alpha^2(1+\phi)(\theta-\phi-1)}{\theta^2-\alpha^2(1+\phi)(\theta-\phi-1)} < \eta < \frac{\alpha^2(1+\phi)(\theta-\phi-1)}{\theta^2-\alpha^2(1+\phi)(\theta-\phi-1)-\alpha\theta(1+\phi)},$$

otherwise indeterminacy arises if and only if

$$\frac{\alpha^2(1+\phi)(\theta-\phi-1)}{\theta^2-\alpha^2(1+\phi)(\theta-\phi-1)} < \eta < \frac{1}{\alpha} - 1.$$

Given the above calibration, indeterminacy emerges when $0.0179 < \eta < 0.0231$ which is within the empirically plausible range estimated by Basu and Fernald (1997). When there are no maintenance activities, multiple equilibria requires $0.0204 < \eta < 0.0256$.[6] Therefore, as in the one-sector model, in the presence of maintenance activities indeterminacy can occur with lower degree of externalities or increasing returns to scale.

Now we focus our analysis on the lower bound of the degree of externalities to further explore the indeterminacy properties,

$$\eta > \eta_{min} = \frac{\alpha^2(1+\phi)(\theta-\phi-1)}{\theta^2-\alpha^2(1+\phi)(\theta-\phi-1)}.$$

It is easy to show that the following first derivatives of η_{min} with respect to θ and ϕ hold:

$$\frac{\partial\eta_{min}}{\partial\theta} > or < 0, \frac{\partial\eta_{min}}{\partial\phi} < 0,$$

implying that the elasticity of depreciation with respect to capital utilization has ambiguous effect on the occurrence of multiple equilibria as there are two opposite effects. On the one hand, higher elasticity implies that more intensive capital utilization leads to a faster depreciation rate, which lowers the net rate of return on capital. On the other hand, from equation (2.3) we can see that as the elasticity parameter θ increases, the marginal benefit of more output increases, which boost the net return on capital.

[6] This case corresponds to a continous time version of Guo and Harrison's (2001) model.

Meanwhile, indeterminacy occurs more easily the larger the elasticity of depreciation rate with respect to maintenance cost rate. When depreciation rate is very sensitive to a percentage change of the maintenance cost rate, it is easier for extra expenditures spending on maintenance to have positive impact on the net return on capital.

2.3.2.2 Constant Capital Utilization

Now we discuss the indeterminacy region when $u_t = u$. Under this formulation, the trace and determinant of J are given by

$$TrJ = \frac{\alpha^2\delta(1+\eta)\rho(1+\phi) - \eta\rho(\delta+\rho+\delta\phi) + \alpha\delta\eta(1+\phi)(\delta+\rho+\delta\phi)}{\alpha^2\delta(1+\eta)(1+\phi) - \eta(\delta+\rho+\delta\phi)},$$

$$DetJ = \frac{\delta[\alpha(1+\eta)-1](1+\phi)(\delta+\rho+\delta\phi)[\rho+(1-\alpha)\delta(1+\phi)]}{\alpha^2\delta(1+\eta)(1+\phi) - \eta(\delta+\rho+\delta\phi)}.$$

The necessary condition for a positive determinant is $\alpha^2\delta(1+\eta)(1+\phi)-\eta(\delta+\rho+\delta\phi) < 0$, indeterminacy requires that the trace to be negative, implying $\alpha^2\delta(1+\eta)\rho(1+\phi) - \eta\rho(\delta+\rho+\phi\delta) + \alpha\delta\eta(1+\phi)(\delta+\rho+\delta\phi) > 0$. This implies proposition 3.

Proposition 3. *In the two-sector model with constant capital utilization and endogenous maintenance activities, when* $[\rho - \alpha\delta(1+\phi)(\delta+\rho+\delta\phi)] - \alpha^2\delta\rho(1+\phi) > 0$, *indeterminacy arises if and only if*

$$\frac{\alpha^2\delta(1+\phi)}{\rho+\delta(1+\phi)-\alpha^2\delta(1+\phi)} < \eta < \frac{\alpha^2\delta\rho(1+\phi)}{[\rho-\alpha\delta(1+\phi)][\rho+\delta(1+\phi)] - \alpha^2\delta\rho(1+\phi)},$$

otherwise indeterminacy arises if and only if

$$\frac{\alpha^2\delta(1+\phi)}{\rho+\delta(1+\phi)-\alpha^2\delta(1+\phi)} < \eta < \frac{1}{\alpha} - 1.$$

Table 2.1: Regions of Indeterminacy

Models	Maintenance	No Maintenance
One-sector Variable Utilization	$0.0866 < \gamma < 2.3333$	$0.1111 < \gamma < 2.3333$
Two-sector Variable Utilization	$0.0179 < \eta < 0.0231$	$0.0204 < \eta < 0.0256$
Two-sector Constant Utilization	$0.0638 < \eta < 0.1764$	$0.0708 < \eta < 0.6342$

We use the same parameterization as above. We derive that $\eta_{min} = 0.0638$ and $\eta_{max} = 0.1764$, which allows the degree of externalities to have a much wider parameterization range. The minimum value remains empirically plausible and smaller than the case where there are no maintenance activities. Therefore the importance of maintenance expenditures on generating multiple equilibria still presents. Moreover, as the elasticity of depreciation rate with respect to maintenance cost rate ϕ increases, the minimum required η decreases.

Table 2.1 compares the regions of indeterminacy for three different economies discussed in this section. It is shown that indeterminacy is easier to obtain in models with maintenance activities than in models without that.

2.3.3 Indeterminacy and Maintenance Expenditures

We've quantitatively shown that maintenance expenditures could reduce the minimum required level of increasing returns to scale. In this subsection, we interpret the economic intuition for indeterminacy in our models.

Starting from an equilibrium path where the rate of discount equals the overall (net) rate of return on capital. Suppose an agent believes that there will be an increase in the rate of return on capital, the agent will reallocate resources from consumption to investment. In order to validate the agent's expectations as a new equilibrium, the return on capital has to be actually increased at higher level of economic activity and the associated first order conditions still hold. The model has two major features that could achieve this. Firstly: a mild degree of returns to scale exhibits in our model economy. The marginal product of capital increases when labour flows from the consumption sector into the investment sector. Secondly, engaging in maintenance activities makes capital better preserved and thus increases its productivity. This results in a higher rate of return on capital as well. Combining these two features, the return on capital can easily increase with higher level of capital stock even if the degree of externalities is small.

2.4 Simulation

In this section, we simulate the discrete time economies involving maintenance activities by introducing both technology and sunspot shocks into the models discussed in Section 2.3. We use Benhabib and Farmer's (1996) discrete time parameterization.[7] The capital share α, is set to 0.35, the quarterly depreciation rate δ is 0.025, the quarterly discount value ρ equals 0.01, and the inverse elasticity of labour supply χ, is 0.

The technology shocks follow the process

$$Z_t = Z_{t-1}^{\omega} \zeta_t,$$

where the persistence parameter ω is calibrated to 0.95. We also introduce i.i.d. sunspot shocks and then the law of motion of this economy becomes

[7] In this paper, the calibrations of both continuous and discrete time models are the same as Benhabib and Farmer (1996) for comparison purpose.

$$\begin{pmatrix} \hat{\Lambda}_{t+1} \\ \hat{K}_{t+1} \\ \hat{Z}_{t+1} \end{pmatrix} = J \begin{pmatrix} \hat{\Lambda}_t \\ \hat{K}_t \\ \hat{Z}_t \end{pmatrix} + R \begin{pmatrix} \hat{\zeta}_{t+1} \\ \hat{e}_{t+1} \end{pmatrix},$$

where e_{t+1} is i.i.d. expectation error which denotes the sunspot shocks.

Table 2.2 shows the U.S. population moments. σ_Y denotes the standard deviation of output and σ_x refers to the standard deviation of variable x. ρ_{xY} is the correlation between variable x and output. We can observe main stylized facts: all variables are procyclical to output. Consumption is less volatile and investment is more volatile than output.

The one-sector model corresponds to Guo and Lansing (2007). In this model, we let externality parameter equal 0.2. The moments derived from the one-sector model is shown in column 'Model 1' of Table 2.2. The table indicates that this model performs reasonably well except that consumption and real wage are too smooth relative to output.

We simulate the two-sector models using the same calibration, except the externality parameter. When we set the externality parameter to 0.2 for the model where the capital utilization is endogenous, it leads to a dynamics of a source instead of a sink as this externality parameter is much larger than the upper bound of our indeterminacy region.[8] Therefore we set it to 0.03. The 'Model 2' column in Table 2.2 shows this two-sector model moments.

In this two-sector model, investment, employment and maintenance expenditures are procyclical but consumption and real wage are countercyclical, although the model

[8] In the discrete time version of this model, local indeterminacy arises when the degree of externalities is within 0.025 and 0.032.

results in reasonable degree of externalities generating multiple equilibria. It is a well-known fact that the artificial data obtained from the models may have some time series properties that are not consistent with the U.S. data. In particular, the counter-cyclical behaviour of consumption in two-sector models has been discussed in several business cycle literature, such as Benhabib and Farmer (1996), Weder (1998) and Harrison (2001). This is due to the fact that when the economy is driven by sunspot shocks, rates of return on capital increase with a higher level of capital stock, implying that the marginal product of labour decreases. To restore the equation (2.1) and (2.2), consumption must decline (Harrison 2001). Benhabib and Farmer (1996) point out that if externalities are sufficiently large then we may get procyclical consumption, however this does not work for our case as the range for the degree of externalities is extremely narrow to remain indeterminacy. Another major counterfactual property in this two-sector model is that investment is much too volatile.

If we consider a two-sector model with constant capital utilization, the model exhibit indeterminacy even η is as large as 0.3. The artificial time series data gives pro-cyclical consumption.[9] The model moments results are shown in the column 'Model 3'. Most features of the model moments are comparable to the U.S. data. It is worth noting that the volatility of investment is quite close to the data in this version of model.

2.5 Conclusion

There is evidence that suggests that expenditures on the maintenance and repair of physical capital. However, with regards to indeterminacy properties, very few papers consider such expenditures in their artificial economies. Hence, we are interested in what

[9] $\eta = 0.2$ (Benhabib and Farmer's calibration) is not sufficient to generate strong procyclical consumption.

Table 2.2: U.S. Moments and Model Moments

Variable	U.S.		Model 1		Model 2		Model 3	
	σ_x/σ_Y	ρ_{xY}	σ_x/σ_Y	ρ_{xY}	σ_x/σ_Y	ρ_{xY}	σ_x/σ_Y	ρ_{xY}
C_t	0.38	0.71	0.09	0.76	0.11	-0.77	0.29	0.42
P_tI_t	3.62	0.97	3.57	0.99	9.58	0.99	3.48	0.98
L_t	0.84	0.83	0.94	0.99	1.08	0.99	0.42	0.96
w_t	1.14	0.76	0.09	0.76	1.11	-0.77	0.29	0.42
M_t	-	-	1.00	1.00	1.12	1.00	1.19	0.96

Notes: The U.S. statistical results of C, PI and L are taken from Pavlov and Weder (2012). Data is quarterly, seasonally adjusted and covers from 1948:I-2006:IV. The information about the real wage w is from King et al. (1988, cited in Weder 2000, p.286). This data series shows the deviations from linear trend, quartly, from 1948:I-1986:IV. An HP-filter is introduced into the artificial time series data.

changes it can make to dynamic properties of an artificial economy once maintenance expenditures are considered. We incorporate maintenance expenditures into two-sector of production model of Guo and Harrison (2001). The minimum externalities required in this paper could be as low as 0.0179 and is empirically plausible.

It has been an issue that a model incorporating both two-sector production and variable capital utilization rate will induce extremely narrow range of increasing returns. It is difficult to replicate the procyclical consumption behaviour. Therefore, we present an alternative model where capital utilization rate is constant over time. Under this model structure, we are able to get pro-cyclical consumption if we allow a sufficient high degree of returns to scale. We conclude that maintenance expenditures are instrumental in generating multiple equilibria: It can make indeterminacy occur under relatively milder degree of externalities compared with its model predecessors.

Appendix 2.A Elasticity of Labour Supply and the Externalities

In this paper we only focus on $\chi = 0$, Hansen's indivisible labour case. In this appendix we illustrate how changes in the inverse elasticity of labour supply χ affect the indeterminacy results, leaving other parameters unchanged. We derive the $\chi - \eta$ relation to illustrate the indeterminacy region for our two-sector variable capital utilization model.

The household's preference is

$$\int_0^{\infty} (lnC_t - \frac{L_t^{1+\chi}}{1+\chi})e^{-\rho t}dt,$$

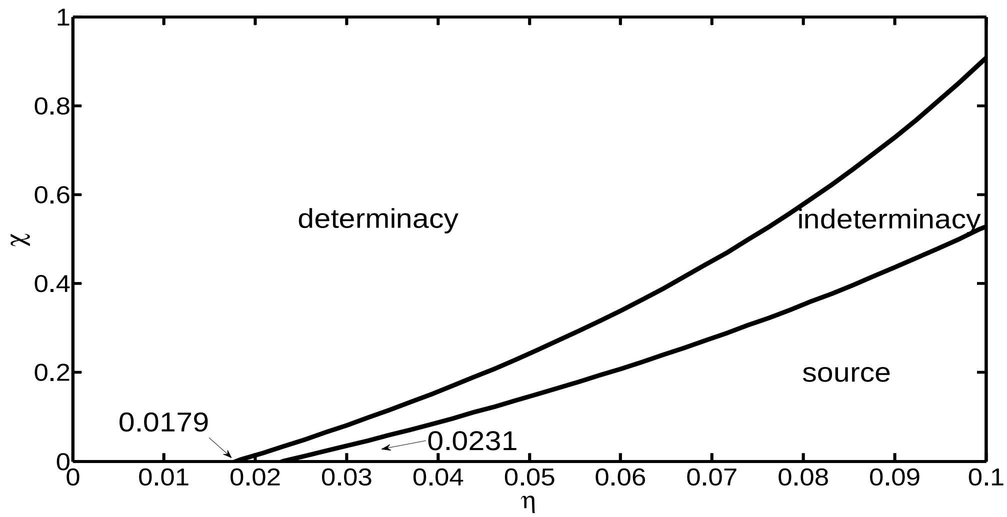
where $\chi > 0$. The trace and determinant of J are

$$TrJ = \frac{\theta\rho[\alpha^2(1+\eta)(1+\phi) - \eta\theta(1+\chi) + \alpha(1+\phi)(\eta\chi - 1)]}{\alpha(1+\eta)\theta(1+\phi)\chi - \eta\theta^2(1+\chi) - \alpha^2(1+\eta)(1+\phi)(1-\theta+\phi+\chi+\phi\chi)}$$
$$+\frac{\alpha(1+\eta)\rho(1+\phi)(\theta-\alpha\phi-\alpha)(1+\chi)}{\alpha(1+\eta)\theta(1+\phi)\chi - \eta\theta^2(1+\chi) - \alpha^2(1+\eta)(1+\phi)(1-\theta+\phi+\chi+\phi\chi)},$$

$$DetJ = -\frac{[\alpha(1+\eta)-1]\theta\rho^2(1+\phi)(\theta-\alpha\phi-\alpha)(1+\chi)}{(\theta-\phi-1)[\alpha(1+\eta)\theta(1+\phi)\chi - \eta\theta^2(1+\chi) - \alpha^2(1+\eta)(1+\phi)(1-\theta+\phi+\chi+\phi\chi)]}.$$

The necessary condition for a positive determinant is $\alpha(1+\eta)\theta(1+\phi)\chi - \eta\theta^2(1+\chi) - \alpha^2(1+\eta)(1+\phi)(1-\theta+\phi+\chi+\phi\chi) > 0$, indeterminacy requires that the trace to be negative, implying $\theta\rho[\alpha^2(1+\eta)(1+\phi) - \eta\theta(1+\chi) + \alpha(1+\phi)(\eta\chi-1)] + \alpha(1+\eta)\rho(1+\phi)(\theta-\alpha\phi-\alpha)(1+\chi) < 0$. We set $\alpha = 0.3$, $\theta = 1.8828$, and $\phi = 0.3828$. Then the relationship between the externality parameter η and the inverse elasticity of labour supply $\chi$is shown in Figure 2.1.

Figure 2.1: Elasticity of Labour Supply and the Externalities



The area between the two curves represents the parameter combinations that lead to indeterminacy. The lowest η value can be achieved when $\chi = 0$, as indicated in Figure 2.1, the corresponding externalities can be as low as 0.0179, as discussed in the paper. Our results are in line with Benhabib and Farmer's (1996) finding that as the value of χ decreases, the lower level of increasing returns to scale is required to obtain indeterminacy.

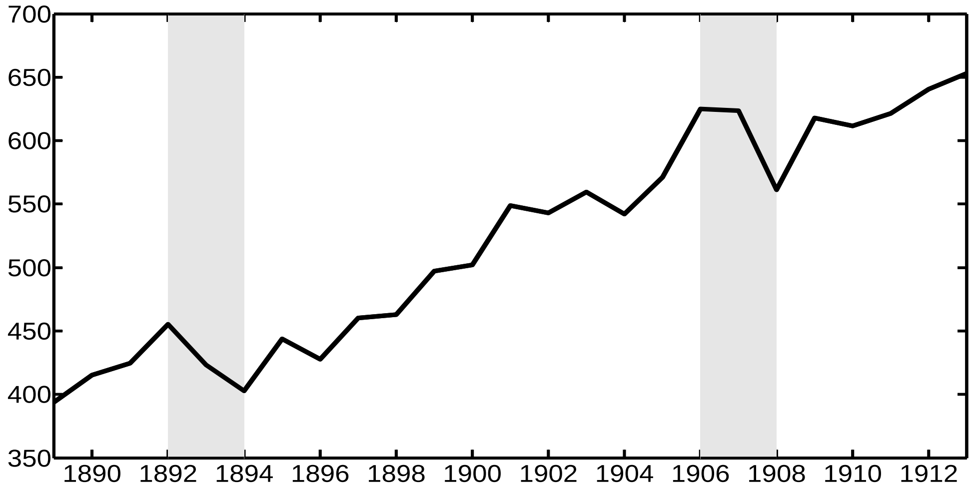
Chapter 3

Business Cycle Accounting of the U.S. Economy: the Pre-WWI Period

3.1 Introduction

The cyclical slumps from 1890 to World War I, overshadowed by the Great Depression, have been almost forgotten by recent economists. In fact, the 1890s were a tumultuous period for the United States' macroeconomy. The National Bureau of Economic Research dates four recessions for the decade: 1890:III-1891:II, 1893:I-1894:II, 1895:IV-1897:II and 1899:III-1900:IV. The contraction beginning in early 1893 was the hardest and the economy's full recovery was painfully long. To put this into perspective, per capita output dipped close to 15 percent and the cumulative economic costs were enormous: it was only by 1901 that the U.S. economy again reached aggregate output trend observed in 1892. Moreover, the recession in 1907 was the last and one of the deepest recessions during the National Banking Era, which eventually led to the establishment

Figure 3.1: Real GNP per Capita in 1889-1913



of the Federal Reserve System. Figure 3.1 shows the undetrended real gross national product (GNP) per capita in 1889-1913.[1]

What caused the depression of the 1890s and what caused the 1893 and 1907 recessions in U.S.? This paper addresses these questions in the context of a neoclassical model of the business cycle. In particular, we apply the Business Cycle Accounting (BCA) method introduced by Chari, Kehoe and McGrattan (2007) to decompose the economic fluctuation into its sources from 1889-1913.

It is imperative to explore the economic fluctuations during the pre-Fed period since it is simpler in important respects. First, the period 1863-1913 was characterized as 'the National Banking Era' during which time there was no central bank and 'lender of last resort', implying that there was little regulation of banks. This Era is a very useful laboratory for studying recessions. Second, we can concentrate our analysis on the sources of shocks that instigate a downturn instead of policy responses that may

[1] Our data is based on an annual basis. To organize our presentation, we focus on the period of 1892-1894 as the most severe economic downturns during the 1890s occur in these years. We also emphasize the big economic slumps from 1906 to 1908. These years are indicated by shaded areas.

have deepened the contractions. Third, there is no 'peso problem' of the reactions of households and firms to the possibility of a government action.[2]

Using the BCA technique we first measure the deviations of the real world economic behaviour from its best outcome implied by the standard growth model. There are four types of deviations: the efficiency wedge is measured as time-varying productivity or exogenous technology shocks. The labour wedge drives a 'wedge' between the marginal product of labour and the marginal rate of substitution between consumption and leisure. The investment wedge distorts the Euler equation. These wedges at face value look like 'taxes' on labour and investment income. The government consumption wedge is defined as the sum of government spending and net export. In a second step, we pin down the wedges that primarily drive the economic fluctuations. With the diagnostic information acquired from the first stage, we are able to evaluate the relative importance of these wedges to economic fluctuations by simulating the models including just one wedge or the combination of wedges. Chari, Kehoe and McGrattan (2007) illustrate that many models with frictions could be reconstructed as a neoclassical model incorporating one or more wedges. Therefore the BCA approach provides useful insight to researchers: it helps them to narrow down the class of models to consider. Lastly, we look for frictions that might affect the economy through these transmission mechanisms (wedges).

We divide our analysis into two sub-periods: 1889-1901 and 1901-1913. Our accounting results show that the efficiency wedge and the labour wedge account for most of the variations in output, labour hours and investment in U.S. during both sub-periods. In particular, the efficiency wedge alone accounts for most of the output behaviour especially its decline in the 1893 and 1907 recessions. The labour wedge is of second importance. The labour hours condition, is primarily driven by the labour wedge

[2] The peso problem refers to "a situation when there is positive probability for a discrete policy shift to occur in a particular period of time". (Persson & Tabellini 1990, p.64)

which almost "perfectly" predicts the decline of hours in 1894 and 1908, followed by the efficiency wedge.

We elabourate on each of these two wedges. First, capital utilization is thought to be an important determinant of movement in the measured efficiency wedge, therefore a promising theory that maps into the efficiency wedge in the growth model should take variable capital utilization into account. Besides variable capital utilization, frictions that captured by the efficiency wedge are explored. The efficiency wedge deteriorates in early 1893, followed by a sluggish recovery, which coincides the number of business failures. These happened again from 1907 during the second sub-period. We conclude that financial market frictions may be partly responsible for the wedge. Second, we decompose the labour wedge into the price markup and the wage markup and illustrate that the wage markup is the dominant aspect of the labour wedge. We find that monetary shocks could be an underlying factor that contributes to the labour wedge, by inducing substantial wage markup during both recession periods.

The rest of the paper is organized as follows. In Section 3.2, we describe the framework of the BCA method including the prototype model and the accounting procedure. Section 3.3 presents the accounting results. In Section 3.4 we discuss the factors that may explain the movements of the wedges and provide some background on our sample periods. Section 3.5 concludes.

3.2 Business Cycle Accounting

3.2.1 The Prototype Growth Model

In this section we describe a neoclassical growth model used in Business Cycle Accounting. This model incorporates four stochastic wedges: the efficiency wedge, the labour wedge, the investment wedge, and the government consumption wedge. These are measures capturing the overall distortion to the optimal decisions made by agents in perfectly competitive markets.

3.2.1.1 Household and Firm

The economy consists of identical infinitely-lived households who are endowed with one unit of time in each period. They choose per capita consumption c_t, supply of labour service h_t and per capita physical capital k_t, taking rent r_t and real wage rate w_t as given. Firms produce goods choosing capital and labour to maximize their profits. Households own the firms and therefore the profits are remitted to households. Time evolves discretely. The population grows at a constant rate g_n; the deterministic rate of technological progress is given by g_z.

A representative household maximizes the present discounted value of his lifetime utility

$$\max_{c_t,h_t,k_{t+1}} E_t \sum_{t=0}^{\infty} \beta^t (1+g_n)^t u(c_t, 1-h_t),$$

subject to the budget constraint

$$c_t + (1+\tau_{xt})x_t = (1-\tau_{ht})w_t h_t + r_t k_t,$$

where x_t is per capita investment in new capital, β is the discount factor parameter. τ_{xt} and τ_{ht} denote the imaginary investment tax rate and labour tax rate, respectively. At face value the labour wedge and investment wedge behave like taxes levied from agent's labour and investment income. The measure of the labour wedge and investment wedge are given by $1 - \tau_{lt}$ and $1/(1 + \tau_{xt})$. These wedges are taxes that distort the agent's first order conditions and prevent the economy from its best outcome. In the absence of market frictions, the value of these wedges should be equal to one.

Given the depreciate rate δ, the law of motion for capital accumulation is given by

$$(1 + g_z)(1 + g_n)k_{t+1} = (1 - \delta)k_t + x_t.$$

The representative firm's problem is to maximize its profit subject to its technology:

$$\max_{k_t, h_t} y_t - r_t k_t - w_t h_t.$$

3.2.1.2 Equilibrium

In this model, the household's preference is represented by

$$u(c_t, 1 - h_t) = log c_t + \theta log(1 - h_t),$$

where θ is a time allocation parameter. Firm produces single output with a Cobb-Douglas production function

$$y = k_t^{\alpha}(z_t h_t)^{1-\alpha},$$

where α stands for the capital share parameter and z_t denotes the productivity shock. $z^{1-\alpha}$ captures the efficiency wedge.

The equilibrium in this economy is defined as a set of prices $\{r_t, w_t\}_{t=0}^{\infty}$ and a set of allocations $\{c_t, h_t, k_t, x_t y_t\}_{t=0}^{\infty}$ satisfying household and firm's first order conditions and their budget constraints. Therefore the economy can be summarized as the following equilibrium equations:

$$\frac{\theta c_t}{1-h_t} = \frac{(1-\tau_{ht})(1-\alpha)y_t}{h_t}, \tag{3.1}$$

$$\frac{1}{c_t}(1+\tau_{xt})(1+g_z) = E_t\{\frac{\beta}{c_{t+1}}[\alpha\frac{y_{t+1}}{k_{t+1}} + (1+\tau_{xt+1})(1-\delta)]\}, \tag{3.2}$$

$$y = k_t^{\alpha}(z_t h_t)^{1-\alpha}, \tag{3.3}$$

$$y_t = c_t + x_t + g_t. \tag{3.4}$$

Equation (3.1) shows the intratemporal labour-consumption trade off. Equation (3.2) is the consumption Euler equation. Equation (3.3) and (3.4) are the production function and the resource constraint faced by the economy. g_t refers to per capita government spending plus net export and is measured as the government consumption wedge.

3.2.2 Accounting Procedure

In this subsection, we apply the accounting procedure to the U.S. economy during 1889-1913 which contains two major business cycle episodes: the depression of the 1890s and the 1907 recession periods. Therefore we divide it into two sub-periods: 1889-1901 and 1901-1913. We firstly derive the series of these four wedges and then feed them back into the prototype growth model to assess the marginal contribution of one wedge or the combination of wedges to the observed fluctuations of output, labour and investment.

The wedges are measured from the data. The primary data source we use is Kendrick (1956) which gives us the annually time series of output, labour, consumption and investment. The data of investment consists of gross private domestic investment, consumption durables and net factor payments. Capital data is constructed using perpetual inventory method. This method requires an initial value of capital. We set k_{1892} as initial capital which is chosen such that the capital-output ratio in year 1892 matches the average capital-output ratios during 1892-1929. Then we generate a time series of capital stock using the capital accumulation law.

In the prototype model all variables are defined in terms of detrended per capita. Thus these variables are divided by resident population to obtain per capita measures of the interest variables and then divided by the long-run productivity growth rate g_z (except per capita labour). Population data is obtained from the Historical Statistics of the United States (2006). g_z is set to be 1.73%, which is based on peak-to-peak measure from 1892-1929.[3] All values are normalized to equal 100 in the peak years before the recessions.

The mensurations of the three wedges are straightforward. Given the time series data, the efficiency wedge is computed from firm's production function (3.3); it measures the efficiency use of factor inputs and shows up in the prototype model as aggregate productivity shocks. An increase in the efficiency wedge stimulates output, which could be the result of a positive aggregate productivity shock. From equation (3.1) we can get the labour wedge. Similarly, an increase in the labour wedge implies increasing in output, as there are less market frictions τ_{ht}. The labour wedge captures the difference between the marginal rate of substitution (MRS) and the marginal product of labour (MPL). An economy with monetary shocks and sticky wedges is equivalent to the growth model with labour wedges, as these detailed models have same distortions as the labour wedge and yield same equilibrium allocations and prices (Chari, Kehoe & McGrattan 2007). The government consumption wedge could represent international

[3] Using this method the two peak points 1892 and 1929 are made comparable in time.

borrowing and lending and is derived directly from Equation (3.4).

The remaining wedge is the investment wedge that captures frictions distorting the intertemporal Euler equation. For example, Bernanke, Gertler and Gilchrist (1999) depict that models with credit market frictions can be reconstructed as the prototype model with investment wedge. However, not all financial frictions are reflected as investment wedges. Chari, Kehoe and McGrattan (2007) provide an example of input-financing friction model to demonstrate that financial frictions in a detailed model may also manifest itself as efficiency wedges rather than investment wedges in the prototype model. Moreover, Buera and Moll (2012) show that a shock to collateral constraints may show up as different wedges in three different forms of heterogeneity models.

The investment wedge $1/(1+\tau_{xt})$ is not directly observable because it is captured by the Euler equation which involves agent's expectation. It is necessary to estimate the stochastic process of the wedges to obtain agent's optimal decision rules. We follow Chari, Kehoe and McGrattan (2007) to assume that the wedges follow first-order autoregressive AR(1) process:

$$s_{t+1} = P_0 + Ps_t + \varepsilon_{t+1}, \varepsilon_t \sim N(0_4, V),$$

where $s_t = [log(z_t), \tau_{ht}, \tau_{xt}, log(g_t)]'$ and ε_t is a vector of independently and identically distributed shocks across time with zero mean and covariance matrix V. These shocks are allowed to contemporaneously correlate across equations. We estimate P_0, P and the lower triangular matrix Q which is defined so that $V = QQ'$ using the maximum likelihood estimation.

To do this, the prototype model is log-linearized around the steady state and the undetermined coefficients method is used. Then the state-space form of the model is given by

$$X_{t+1} = AX_t + B\varepsilon_{t+1},$$

$$Y_t = CX_t + \omega_t,$$

where $X_t = [log(k_t), log(z_t), \tau_{ht}, \tau_{xt}, log(g_t), 1]'$ and $Y_t = [log(y_t), log(x_t), log(h_t), log(g_t)]$.[4] ω_t denotes the measurement error.

The matrix A summarizes the coefficients relating k_{t+1} to X_t and the matrix P_0 and P. The matrix C consists of the coefficients linking Y_t to X_t.

We use the parameters proposed in existing studies in the real business cycle theory. The capital share α equals 0.3, the annual depreciation rate δ is 5 percent, the discount factor β equals 0.95 and the time allocation parameter is set to be 2.24. The population growth g_n is 1.48 percent which is the average population growth rate over the period 1892-1929.

The steady state levels of these four wedges are obtained as follows. The steady state value of the efficiency wedge, labour wedge and government consumption are the sample mean of their measured values over the period of 1892-1929. The steady state level of the investment wedge is given by $\tau_x = \alpha\overline{(\frac{y}{k})}\frac{1}{\frac{g_z}{\beta}-(1-\delta)} - 1$, which is obtained from the steady state expression of the Euler equation, where $\overline{(\frac{y}{k})}$ refers to the average output-capital ratio over the same period. Table 3.1 summarizes the calibrations of the parameters. With these parameter values assigned, we can obtain the process governing the stochastic wedges and then derive the realized value of the investment wedge.

Our objective is to evaluate the fractions of the movements in macroeconomic aggregates that the four wedges account for. Feeding each wedge or the combination of wedges into the benchmark model, we can evaluate which wedges attribute the most to the

[4] X_t contains capital and four wedges. Y_t includes the observed or easily obtained variables.

Table 3.1: Calibrations

Parameters	Values
Net technological progress growth g_z	0.0173
Net population growth g_n	0.0148
Capital share α	0.3000
Discount factor β	0.9500
Time allocation parameter θ	2.2400
Annual depreciation rate δ	0.0500
Steady state value of efficiency wedge z	1.2969
Steady state value of labour wedge τ_h	-0.0568
Steady state value of investment wedge τ_x	-0.1737
Steady state value of government consumption wedge g	0.0836

fluctuations in output, labour and investment. Note that by construction, we can exactly replicate the data if we feed in all of the four wedges jointly, as all of the market frictions are captured by these four wedges.

3.3 Decomposition Results

In this section we show the realized wedges using the method described in Section 3.2. The estimated stochastic process for the wedges is reported in Table 3.2. Then we simulate the models by feeding in each wedge individually to assess the fluctuations of the simulated output and other endogenous variables.

Table 3.2: Parameters of Vector AR(1) Stochastic Process

Coefficient Matrix P on Lagged States	Coefficient Matrix Q where $V = QQ'$
$\begin{bmatrix} \underset{(0.1472)}{0.7402} & \underset{(0.1022)}{0.1295} & \underset{(0.1687)}{0.2689} & 0 \\ \underset{(0.2875)}{-0.0947} & \underset{(0.1724)}{0.8834} & \underset{(0.3129)}{0.1799} & 0 \\ \underset{(0.2212)}{-0.0472} & \underset{(0.1417)}{0.1000} & \underset{(0.2234)}{0.9897} & 0 \\ 0 & 0 & 0 & \underset{(0.1089)}{0.7749} \end{bmatrix}$	$\begin{bmatrix} \underset{(0.0069)}{-0.0519} & 0 & 0 & 0 \\ \underset{(0.0252)}{0.0124} & \underset{(0.0382)}{0.0952} & 0 & 0 \\ \underset{(0.0175)}{-0.0124} & \underset{(0.0117)}{-0.0553} & \underset{(0.0114)}{-0.0353} & 0 \\ 0 & 0 & 0 & \underset{(0.0455)}{0.2768} \end{bmatrix}$

Overall, in both periods, the efficiency wedge plays a central role in output and investment fluctuations. The labour wedge is of second importance. labour hours, is

Table 3.3: The Contribution of the Four Wedges to the Output Drops

Variables	1892-1894	1906-1908
Data	-14.41%	-13.36%
Efficiency	-13.55%	-15.38%
labour	-6.37%	-5.29%
Investment	5.76%	6.51%
Government Consumption	-0.20%	0.91%

primarily driven by the labour wedge. The investment wedge drives these variables to the 'wrong' directions. The role of the government wedge is feeble.

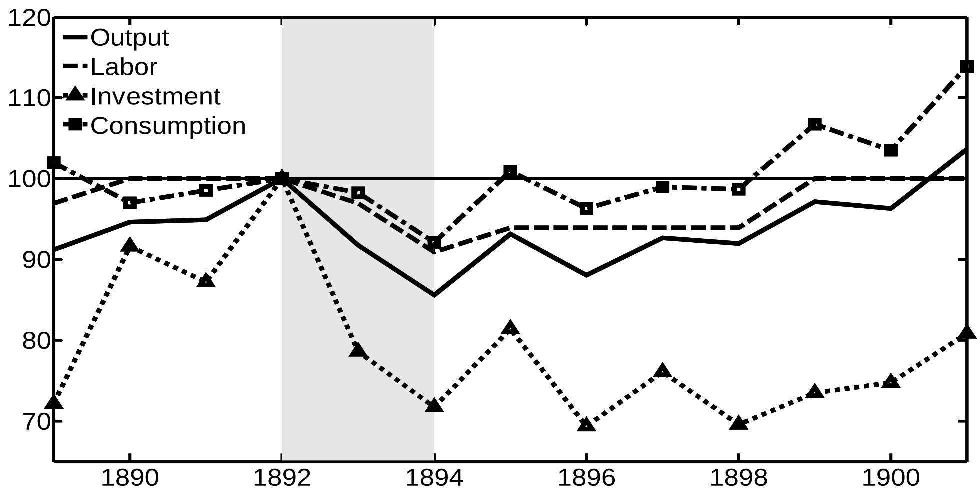
In terms of the depth of the recessions, Table 3.3 depicts the drops of the observed output as well as the simulated data during the recession years (from the peak to the trough) of our interest. The second and third columns show the percentage of output drops between year 1892 and 1894, 1906 and 1908, respectively. We can observe that in both recessions, the efficiency wedge accounts for the most of the output drops, followed by the labour wedge. The investment wedge, on the other hand, increases output.

In the following subsections we describe the results of the accounting procedure to the two selected U.S. business cycle episodes in details.

3.3.1 The Depression of the 1890s

Figure 3.2 shows the paths of output, labour, investment and consumption for the U.S. over the period 1889-1901. All variables are nomalized to equal 100 in 1892. The economic contraction begins in the beginning of 1893 and reaches the trough in 1894. In this two years output is at over 14 percent below the trend. The economy then recovers until 1895 and is hit by another recession. Not until 1897 does the economy recover gradually and go back to trend. labour hours, investment and consumption undergo similar unsteadiness as output. Hours drops 9 percent below their 1892 level in 1894.

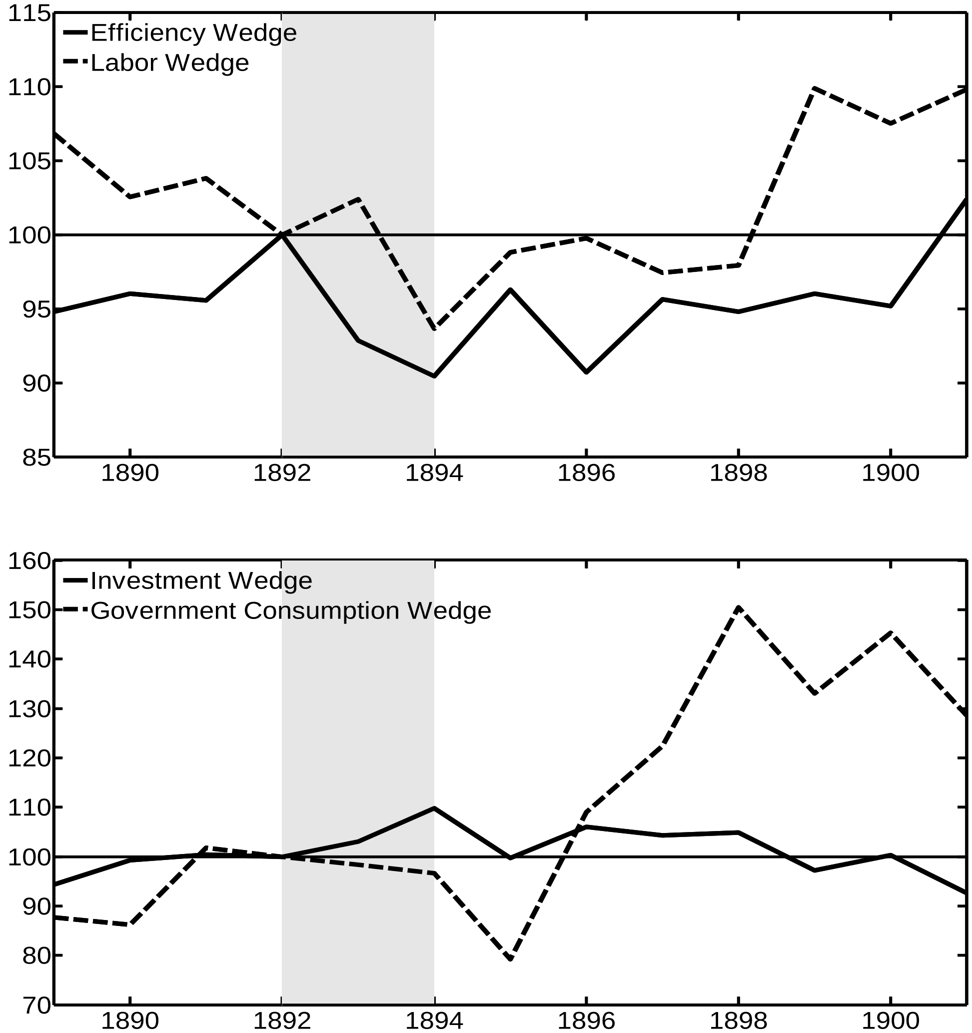
Figure 3.2: U.S. Output, Labour, Investment and Consumption 1889-1901



Meanwhile, investment declines by more than 28 percent and stays depressed until early 20th Century. Hoffman (1956) points out that the long duration of low investment in major areas of economic activity such as investment in railroads were significant factors shaping the depression and attributed to the retarded recovery. Consumption is 7 percent below its 1892 level.

Figure 3.3 displays the realization of the four wedges in U.S. over the same period: the efficiency wedge $z_t^{1-\alpha}$, the labour wedge $1 - \tau_{ht}$, the investment wedge $1/(1 + \tau_{xt})$ and the government consumption wedge g_t. The efficiency wedge drops sharply from early 1893, followed by another drop in 1895. This is consistent with the feature of output and investment data. The labour wedge follows the same recession pattern in 1894 only and improves continuously since then. On the other hand, the investment and government consumption wedge do not capture the behaviour of neither the recession nor the recovery during 1889-1901. These relationships are further supported by Table 3.4 which depicts the standard deviations of the four wedges relative to output and their cross correlations with output. The efficiency wedge and labour wedge show very

Figure 3.3: Measured Wedges, 1889-1901



strong positive correlations with output, with a contemporaneous cross correlation of 0.94 and 0.66, respectively. The investment wedge is negatively correlated with output, both contemporaneously and for a lead and a lag. The government consumption wedge is somewhat positively correlated with output.

Next, we show decomposition results for output, labour, investment and consumption. Figure 3.4 to 3.7 plot the model outcomes of feeding in each wedge individually or combination of wedges. The first panel of these figures compares the model results with

Table 3.4: Properties of the Wedges 1889-1901

Wedges	Standard Deviation	Cross Correlation		
		-1 (Lag)	0	1 (Lead)
Efficiency	0.6804	0.0504	0.9446	0.0753
labour	1.0593	0.3571	0.6600	0.3865
Investment	0.9922	-0.1344	-0.7552	-0.1458
Government Consumption	4.8531	0.1969	0.2925	0.5507

the efficiency wedge or labour wedge with data. We can see that there is a remarkable coincidence between simulated model with efficiency wedge and time path of output. The efficiency wedge is also important in explaining the movements of investment, although it predicts an excessive drop from 1892 to 1894 and a faster recovery since 1897 compared to the observed investment data. By 1894, simulated investment drops by more than 39 percent while actual investment only drops by 28 percent. The efficiency wedge plays a less role in driving the movements of labour hours. On the other hand, it contributes to neither the sharp decline nor the rapid recovery of consumption.

Now we evaluate the contribution of the labour wedge. The graph of the simulated output has a similar pattern as the actual output in both the recession and recovery periods, however the role of the labour wedge is smaller than that of the efficiency wedge. For example, the predicted output falls due to the labour wedge is approximately 7.7 percent less than the drop of output data in 1894. With regards to its contribution to labour hours, by 1894, the model with the labour wedge completely replicates the behaviour of labour: it predicts a 9 percent decline in labour, which is almost the same as the change in the observed labour data. We conclude that it is the major culprit for the declining labour hours in recession and is also responsible for its recovery. The artificial model predicts a decline in investment from 1892 to 1894, followed by another drop in 1895, but it underestimated the actual drop of investment. The labour wedge plays no role in consumption.

Figure 3.4: Output Decomposition 1889-1901

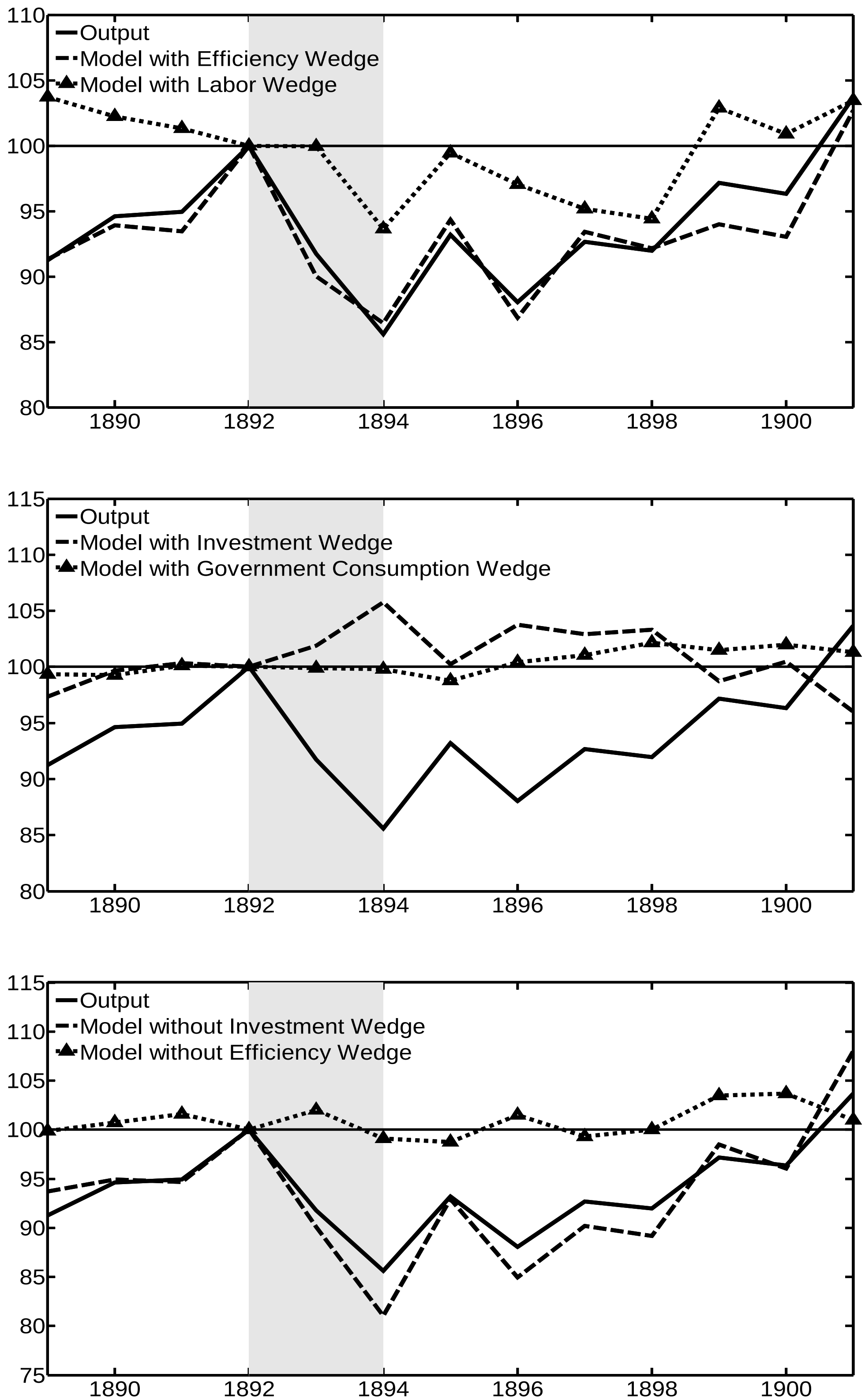
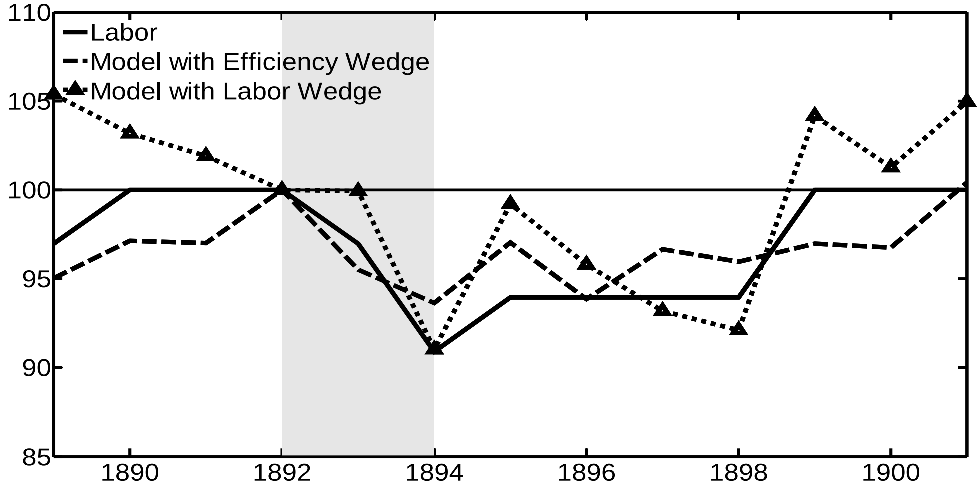
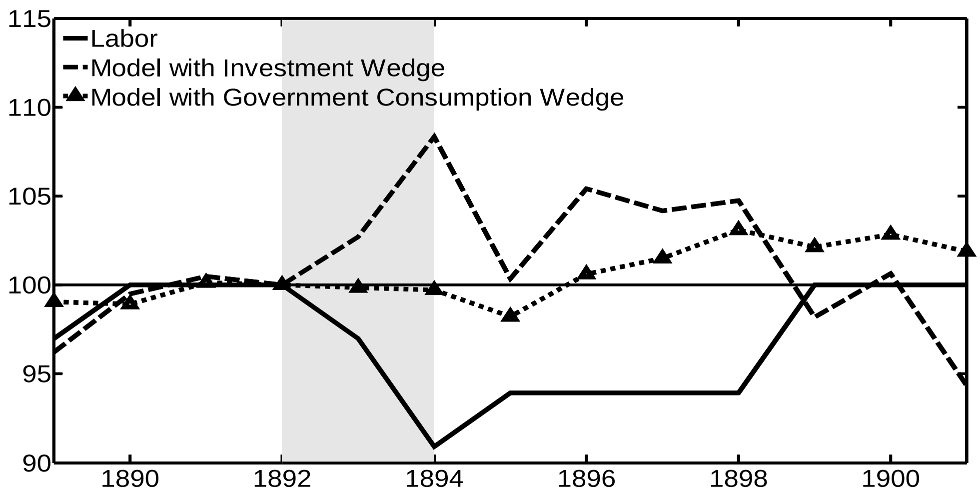


Figure 3.5: Labour Decomposition 1889-1901





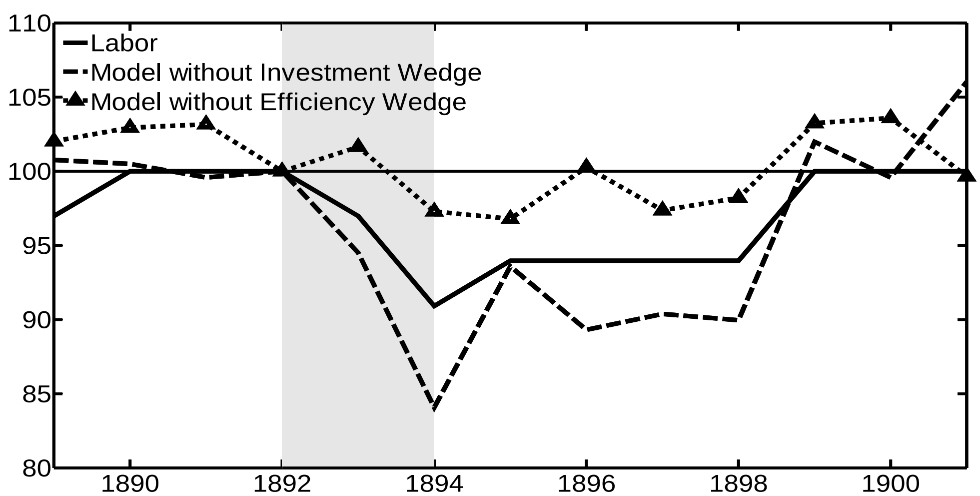


Figure 3.6: Investment Decomposition 1889-1901

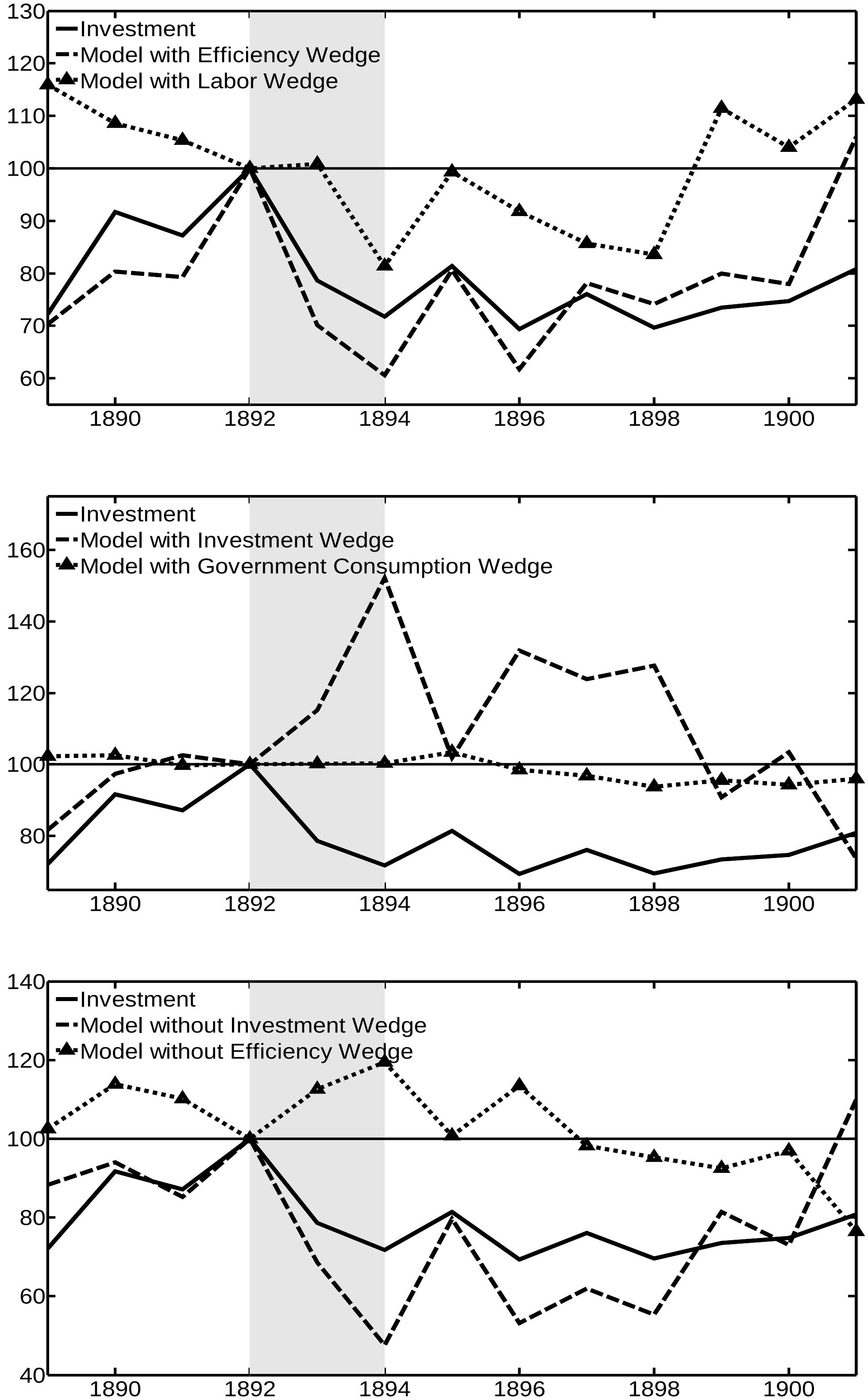
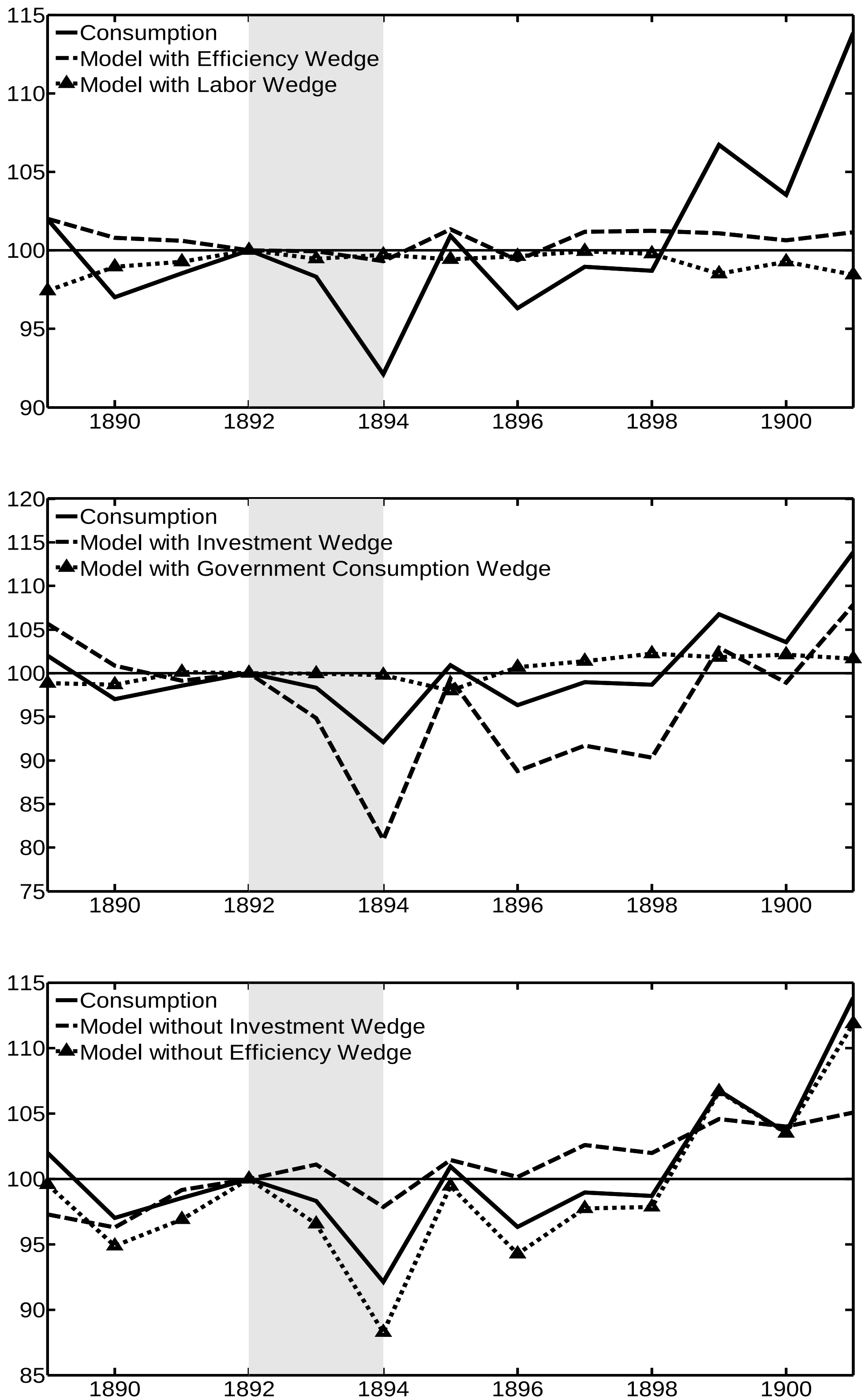


Figure 3.7: Consumption Decomposition 1889-1901



The second panel of Figures 3.4 to 3.7 exposits the contribution of the investment wedge and the government consumption wedge on variables interested. As shown in these graphs, the observed and the predicted output and labour hours incorporating each of these two wedges move in opposite directions. In particular, both wedges fail to explain the downturn and recovery of the economy. Whereas the investment wedge plays an important role in the fluctuations of consumption since the model with investment wedge replicates the development of consumption. Notably, it almost completely accounts for the recovery of consumption in 1895.

The third panel displays the contribution of the joint wedges which 1) show that the distortions that manifest themselves as investment wedges are not determinants of the fluctuations of most variables but consumption. and 2) demonstrates the importance of the efficiency wedge on output, labour and investment. As shown in the graphs, the efficiency wedge, labour wedge and government consumption wedge together accounts for almost all of the fluctuations in output. Moreover, if we feed in all of the wedges except efficiency wedge into the prototype model, only simulated consumption data is on the right track.

3.3.2 The 1907 Recession

We apply the same accounting procedure over the period of 1901-1913. We set 1906 as the base year; therefore all variables are scaled to equal 100 in 1906. In Figure 3.8, we can observe that output decreases by more than 13 percent from 1906 to 1908. At the same time, labour and investment fall drastically as well. It is followed by a quick but incomplete recovery, and the economy is still around 5 percent below the trend in 1913.

Figure 3.9 exposits that the efficiency wedge has similar movement patterns as output

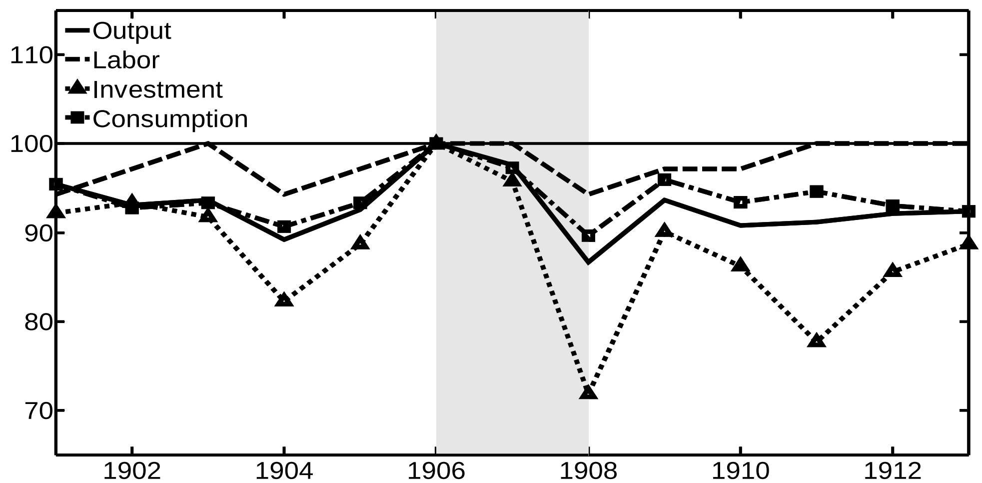
Table 3.5: Properties of the Wedges 1901-1913

Wedges	Standard Deviation	Cross Correlation		
		-1 (Lag)	0	1 (Lead)
Efficiency	1.3295	0.0863	0.7147	0.1368
labour	1.0080	-0.1950	0.2260	-0.2071
Investment	1.0824	-0.0015	-0.6667	-0.1119
Government Consumption	3.0201	0.3902	-0.1634	-0.0021

and investment in both recession and incomplete recovery periods. It is more than 10 percent below the trend in 1908 and remains 7 percent below the trend in 1913. The condition of the labour wedge also deteriorates due to the 'panic' in 1907, but it improves and surpasses the trend line since then. The behaviour of the government consumption wedge in this recession is different from that in early 1893. The government consumption wedge is slightly worsened from 1892-1894 but largely improved from 1906-1908. In Table 3.5 we show the features of the wedges during the period 1901-1913. The contemporaneous cross correlation of the efficiency wedge with output is 0.7147 and the correlation between the labour wedge and output is much weaker, 0.2260. In contrast, the investment and government consumption wedges are negatively correlated with output. The results suggest that over this period the efficiency wedge plays a larger role relative to other wedges.

The decomposition results for output, labour, investment and consumption are shown in Figure 3.10 to 3.13. In general, the results are quite similar to that of 1890s except the finding that although the labour wedge attributes to the slowdown of output during the recession and the initial recovery, in the following phase it fails to capture the behaviour of output. This is also indicated by the lower correlation between the labour wedge and output in this period than 1890s.

Figure 3.8: U.S. Output, labour, Investment and Consumption 1901-1913



3.3.3 Results Comparison

Few economic literature provides discussions of individual business cycles in the U.S., with a notable exception of the Great Depression, as these have not been a concern of most economists. It is useful to compare our results with Chari, Kehoe and McGrattan's (2007) findings on the U.S. Great Depression and the entire postwar period in order to verify that whether their conclusions apply to the pre-WWI recessions.

Chari, Kehoe and McGrattan (2007) find that the efficiency wedge and labor wedge together account for the most of the observed fluctuations of the U.S. economy. In particular, the deterioration of these wedges are the major culprits of the economic downturns during the Great Depression and the 1982 recession. Our BCA analyses of the depression of the 1890s and the recession of 1907 lead to the same conclusion. Therefore, to understand the U.S. business cycles and the causes of recessions, we should focus on the frictions or shocks that affect the economy through the efficiency wedge and labor wedge, although the primitive shocks may be specific to different recessions.

Figure 3.9: Measured Wedges, 1901-1913

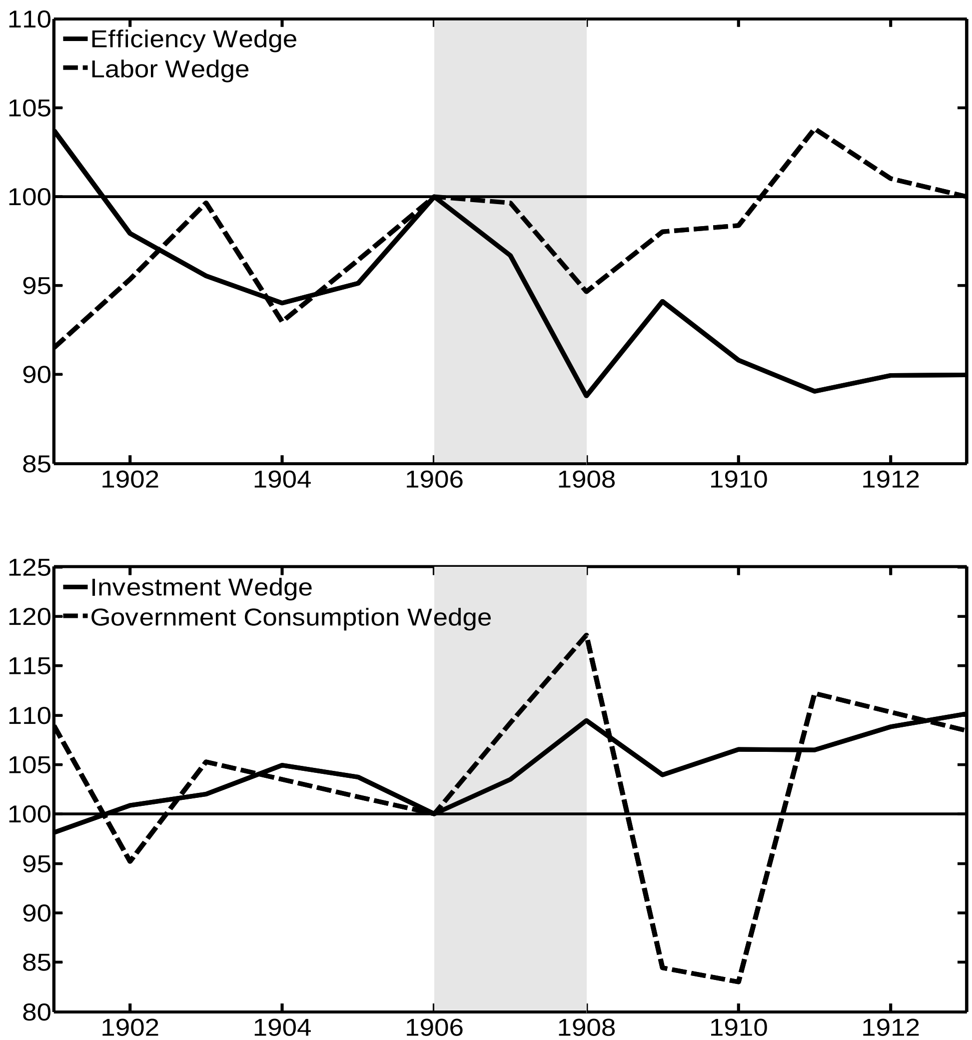


Figure 3.10: Output Decomposition 1901-1913

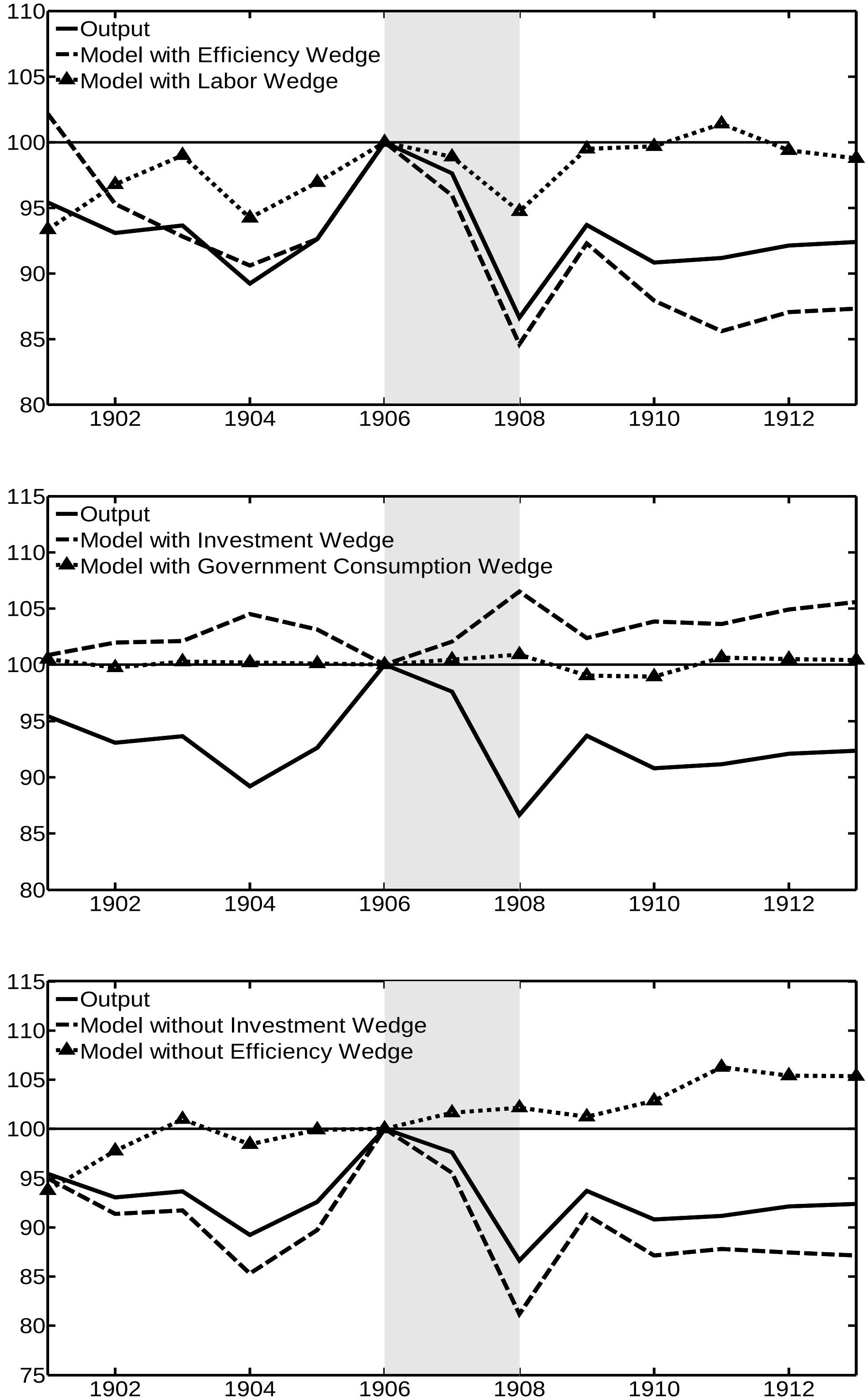


Figure 3.11: Labour Decomposition 1901-1913

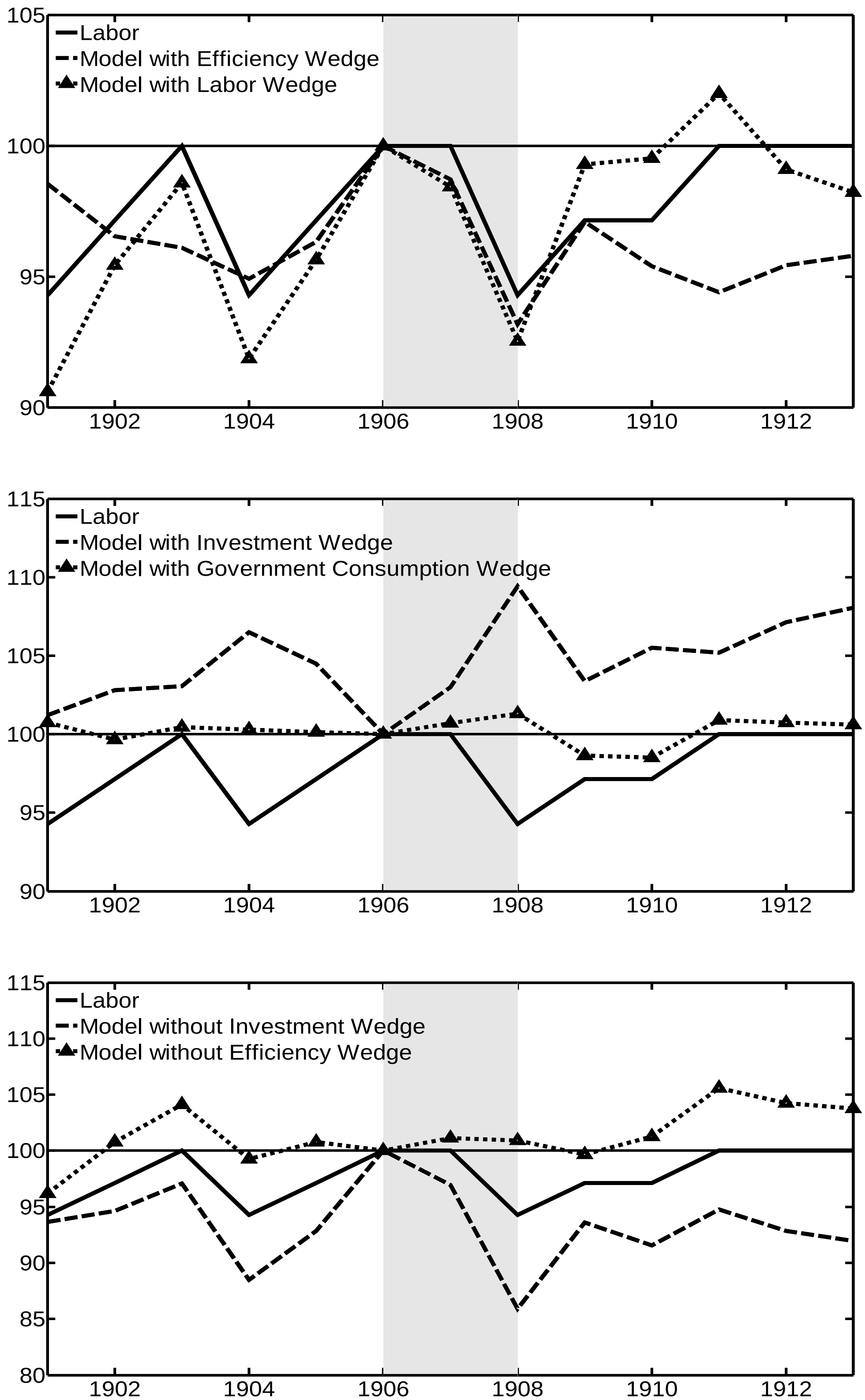


Figure 3.12: Investment Decomposition 1901-1913

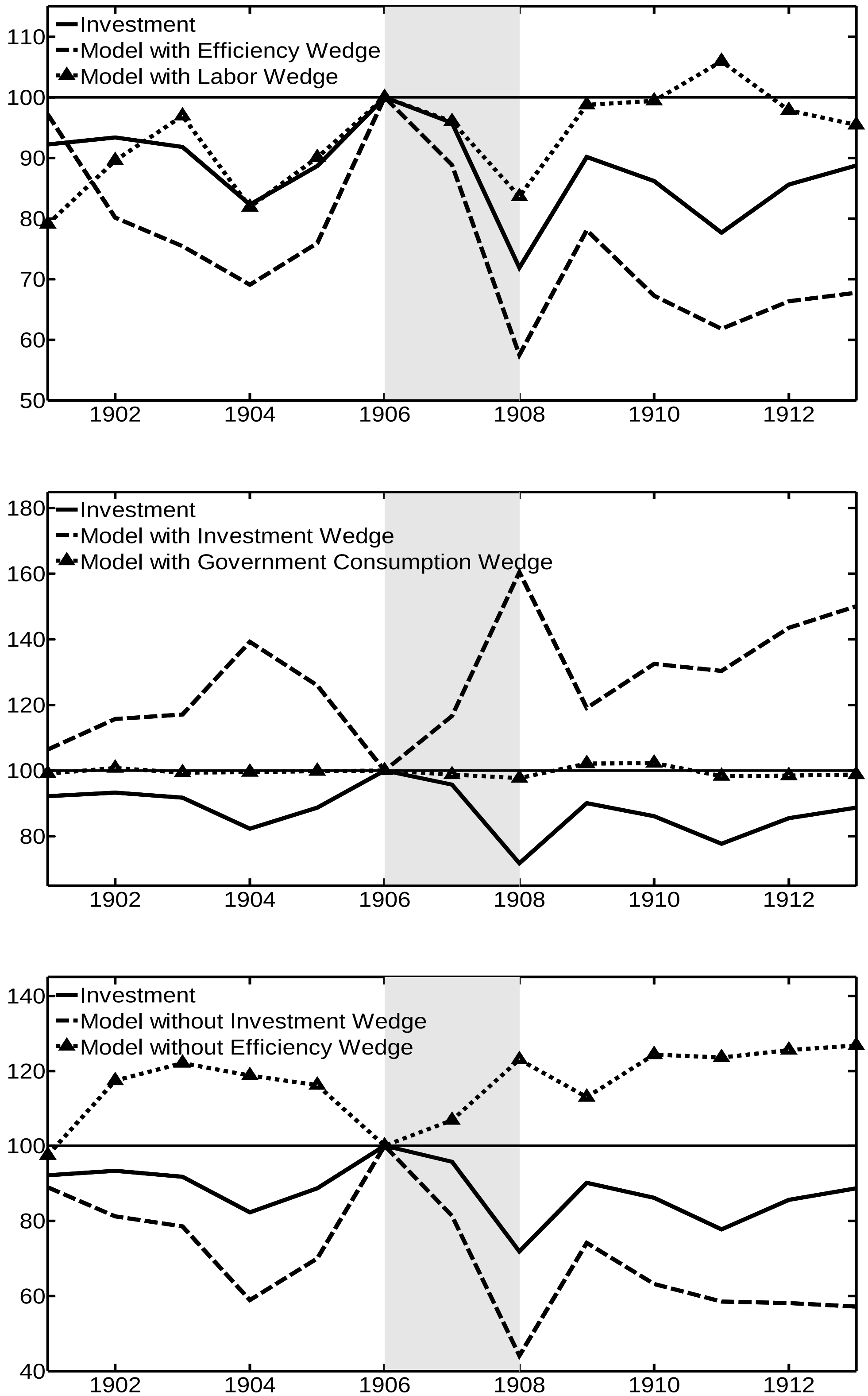
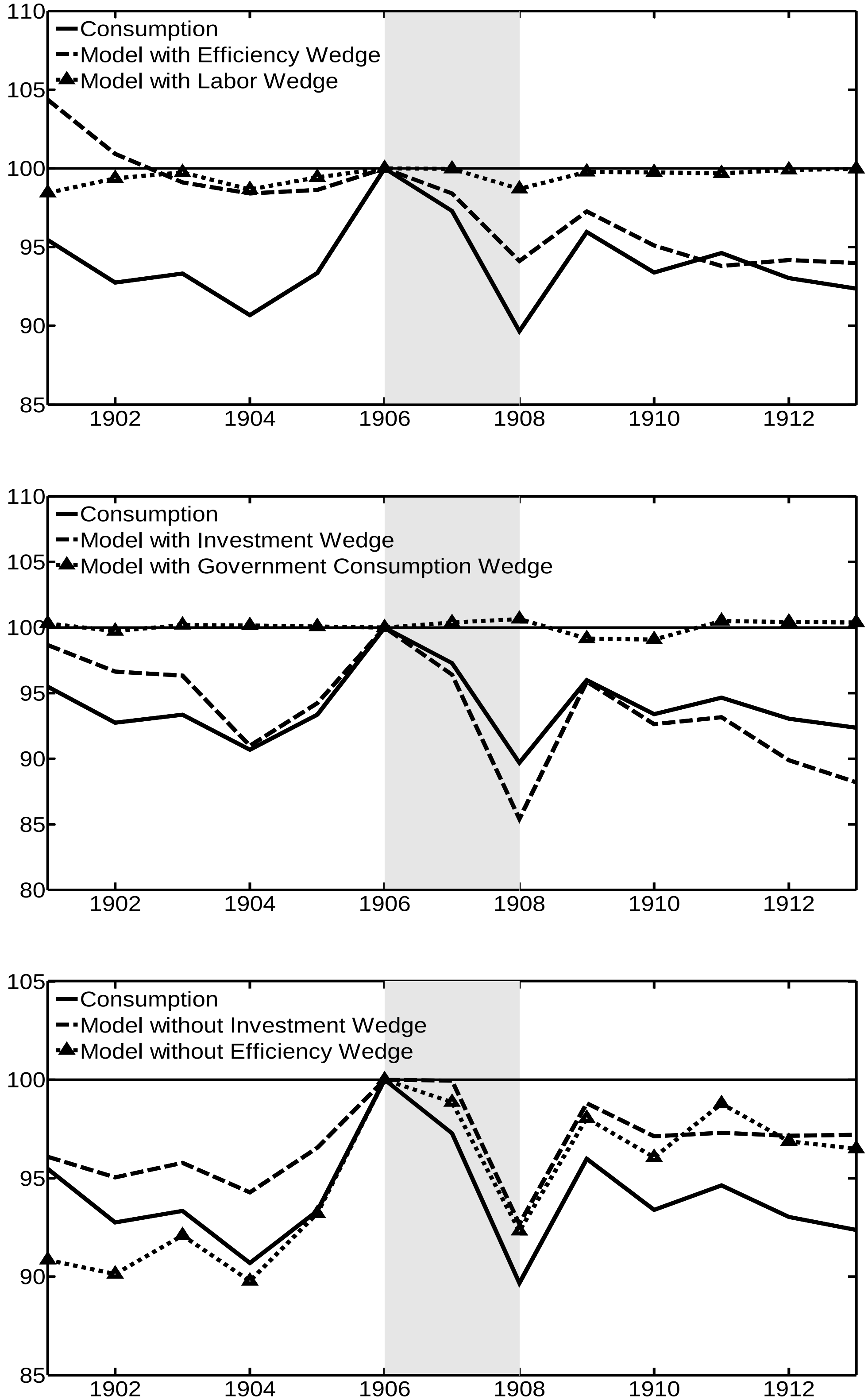


Figure 3.13: Consumption Decomposition 1901-1913



3.4 Discussion

The findings in the previous section indicate that the fluctuations of output and investment are primarily driven by the efficiency wedge. The variation in labour hours mainly appear from the labour wedge. The investment wedge only accounts for the movements of consumption. Although none of the wedges could be safely ignored, the efficiency and labour wedges are of most importance in explaining the economic fluctuations compared to other wedges in both sub-periods. In this section we go one step further to understand what frictions are captured by these wedges and why they deteriorate during the recessions. More specifically, we materialize these wedges in terms of various macroeconomic variables.

3.4.1 Understanding the Efficiency Wedge

The Business Cycle Accounting results highlight the contribution of the efficiency wedge in economic fluctuations during the pre-1914 period. So what are the primitives that might have caused the deteriorations of the efficiency wedge during the recessions?

The efficiency wedge captures frictions in production. A shift in the aggregate technology could be one important source of such production deviation. In our benchmark model, the efficiency wedge $z_t^{1-\alpha}$ is defined in a way such that

$$log(z_t) = [log(y_t) - \alpha log(k_t) - (1-\alpha)log(h_t)]/(1-\alpha),$$

where the capital utilization rate is assumed to be constant over time. This is essentially the measure of Solow residuals. Whereas, there is abundant evidence that capital utilization vary significantly over time. Harrison and Weder (2009) stress that procyclical capital utilization could be an important transmission mechanism of business fluctuations, motivated by Bresnahan and Raff (1991) finding that more than 20 percent of capital stock was idle in 1933. This implies that the Solow residual measure of production efficiency tends to overstate the aggregate productivity fluctuations. Moreover, Burnside, Eichenbaum and Rebelo (1995) argue that cyclical movement in capital utilization is an important determinant of movement in the total factor productivity (TFP). Therefore, it is necessary to isolate the effect of variable capital utilization from the efficiency wedge if one aims to understand the behaviour of the 'true' productivity and the frictions that captured by the efficiency wedge.

If we allow for variable capital utilization, the production function that follows Harrison and Weder (2009) is now given by

$$y_t = (u_t k_t)^{\alpha} (z_t' h_t)^{1-\alpha},$$

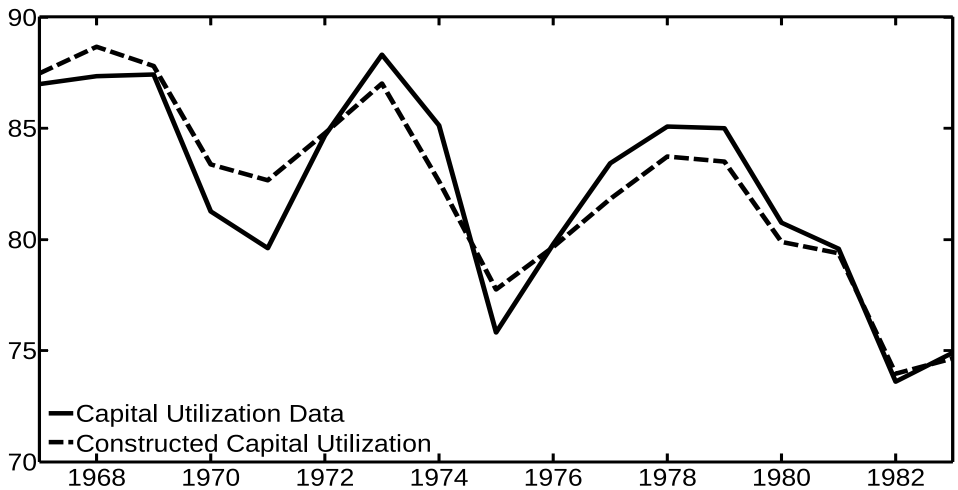
where u_t denotes the capital utilization rate. $(z_t')^{1-\alpha}$ is the measure of the utilization adjusted productivity and can be derived from our two different techology specifications:

$$(z_t')^{1-\alpha} = \frac{z_t^{1-\alpha}}{u_t^{\alpha}}.$$

As capital utilization data is not directly available for pre-WWI period, we need to construct this data series making use of the capital utilization data from 1967 to 1983 and the definition of the capacity utilization rate: the ratio of actual output to the potential output. The source of actual and potential output data from 1889 to 1983 is Hall and Gordon (1986). Capital utilization data is obtained from the Board of Governors of the Federal Reserve System database. We estimate the simple linear relationship between the capital utilization rate and actual-potential output ratio using ordinary least squares estimation. Then we use this relation to infer the capital utilization rate prior to 1967.

Figure 3.14 compares the observed and estimated utilization rate over 1967-1983. Figure 3.15 plots the constructed capital utilization series $\{u_t\}$ along with output, indicating that the capital utilization rate is procyclical and strongly correlated with the movements in output. We can also observe in Figure 3.15 that the fluctuations of capital utilization also coincide with that of the efficiency wedge.

Figure 3.14: Capital Utilization during 1967-1983



Once we construct the capital utilization rate, we can derive a new series for total factor productivity. Figure 3.16 plots the efficiency wedge, the adjusted TFP and the Kendrick's (1956) measured TFP series. The movement of the adjusted TFP is smaller than the measured efficiency wedge, indicating that the role of the TFP is exaggerated without considering the factor hoarding. This is consistent with Chari, Kehoe and McGrattan (2007), Klein and Otsu (2013) finding that the variable capital utilization specification downplays the importance of the efficiency wedge. Moreover, as can be seen from Figure 3.16, the three measures of TFP arrive at similar results.[5]

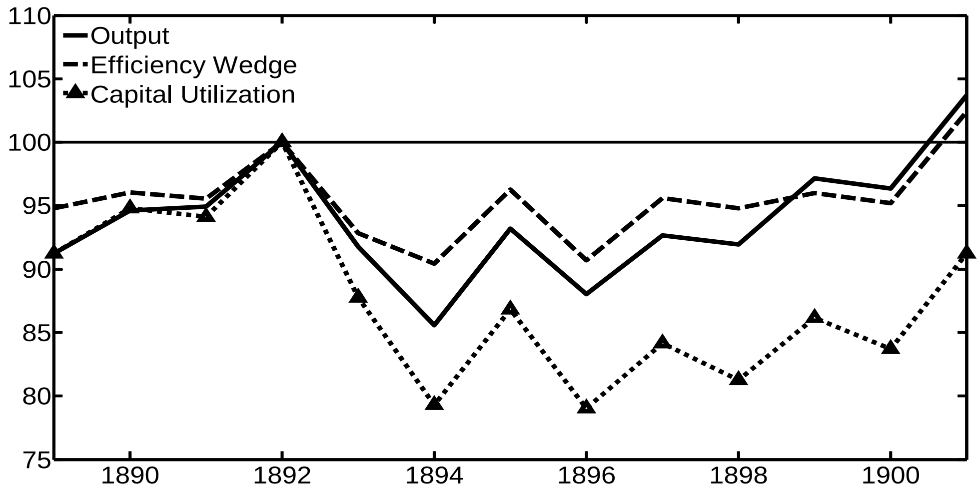
[5]Kendrick's measure is based on a linear production function. Then the TFP index is the weighted arithmetic mean of capital and labour input indices.

Then we feed the adjusted TFP into our benchmark model, the simulation results are shown in Figure 3.17. It predicts milder output decline from 1892 to 1894 in comparison with model of the efficiency wedge, indicating that variable capital utilization is an important transmission mechanism of output fluctuations. But there must be some other frictions that also affect the efficiency wedge.

Now we look for possible candidates for causing the deterioration of the efficiency wedge. It has long been recognized that a firm's investment and production decisions are largely determined by its level of financial constraint. Research such as Hsieh and Klenow (2007), Buera and Moll (2013), Ziebarth (2011), Moll (2014) show that resource misallocation across firms is an important source of low TFP. In their models, the abilities to acquire capital differ across firms due to their different constraints. Those firms who can borrow at lower interest rates would have lower marginal product of capital than those who face higher financial constraints. It is obvious that in the absence of such distortions, output would be higher (Hsieh & Klenow 2007). Therefore this type of financial friction can show up as the efficiency wedge. However, to quantify this relationship it is necessary to use microeconomic evidence which we do not have access to, as the firm or plant-level data are scarce prior to WWI.

Therefore we use another way to evaluate whether the financial constraint deteriorated the efficiency wedge during the Pre-WWI period. Interest rate spread is regarded as the most basic concept of a financial friction as it generates agency frictions within firms or financial intermediaries (Hall 2013). During a financial crisis interest rate spread shots up and financial institutions' access to capital is constrained, which would prevent agencies from generating their optimal choices and induce production inefficiency. We use the difference between corporate bond yield and commercial paper rate as a measure

Figure 3.15: Output, Efficiency Wedge and Constructed Utilization 1890-1901, 1901-1913



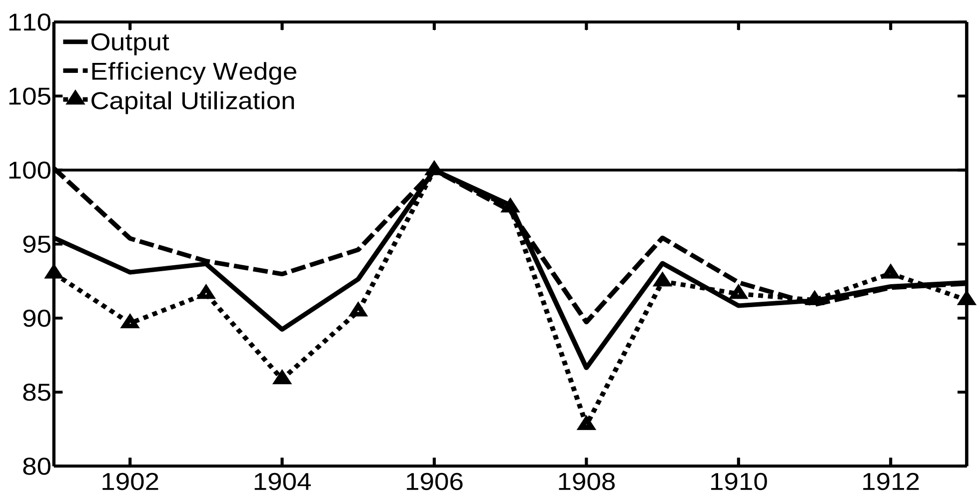


Figure 3.16: The Efficiency Wedge, the Adjusted TFP and Kendrick Measure of TFP

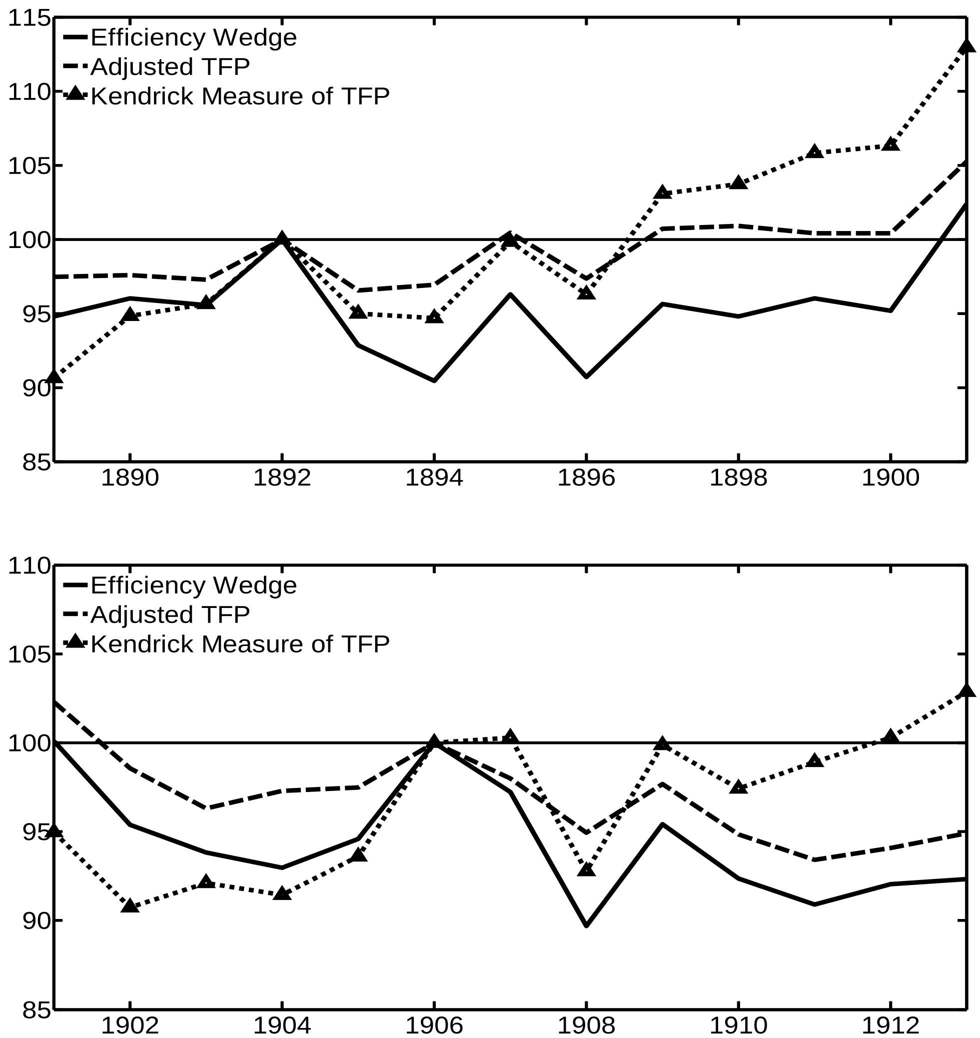


Figure 3.17: Output and Simulated Output

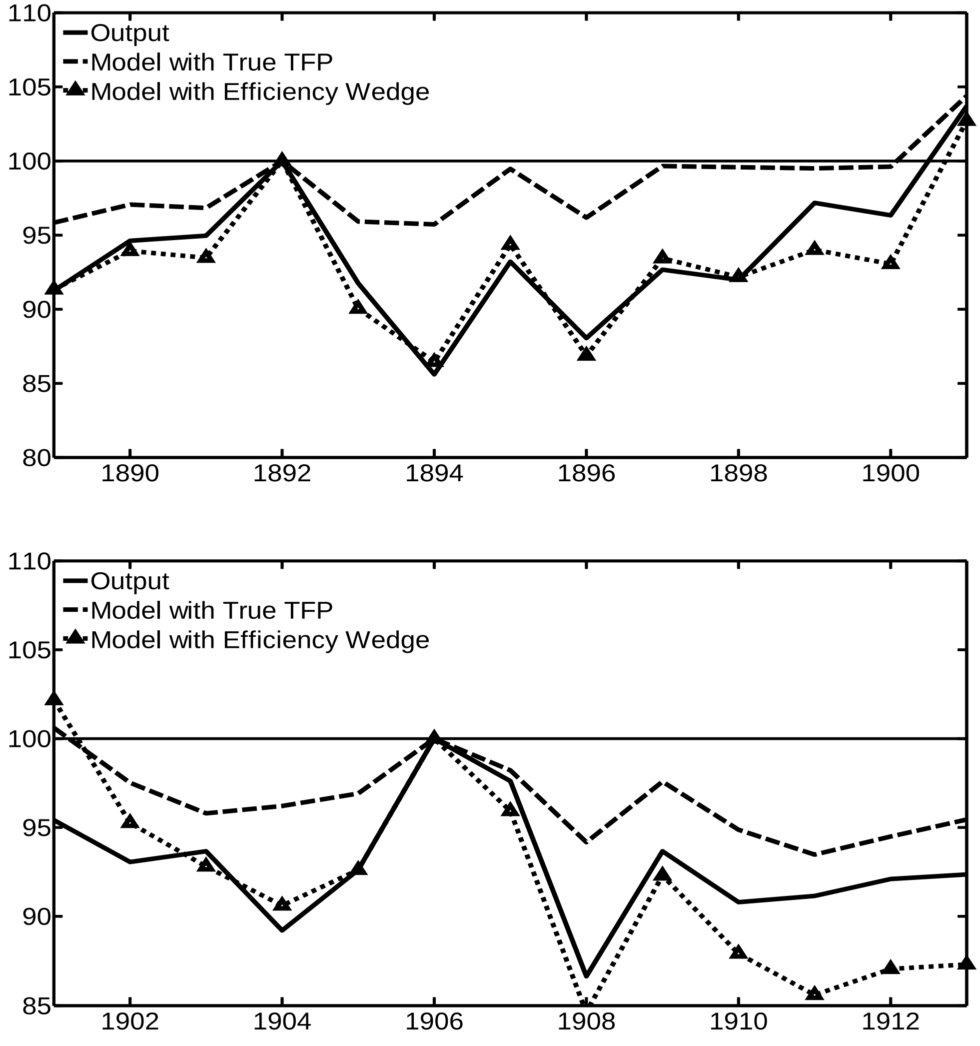
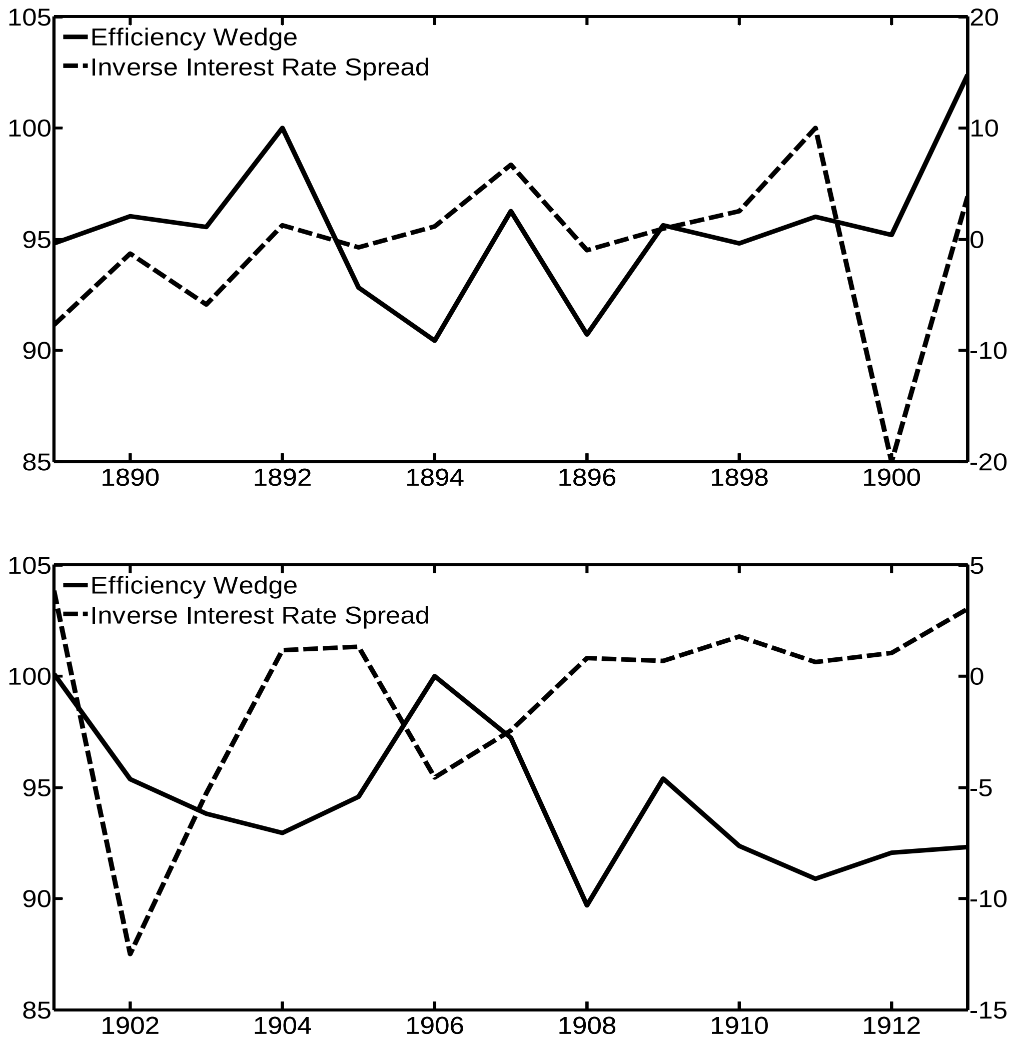


Figure 3.18: The Efficiency Wedge and Interest Rate Spread



of interest rate spread.[6] Figure 3.18 reports the fluctuations of the efficiency wedge (left y-axis) and the inverse of interest rate spreads (right y-axis). We can observe that in the recessions, the deterioration of the efficiency wedge is not induced by the interest rate spread.

Business failure is also an important sign of financial sector difficulties as it implies higher debtor insolvency. Under this circumstance, it becomes more difficult and costly

[6] All sources of data are shown in the Appendix 3.A.

for firms to obtain credit (Bernanke 1983). Chari, Kehoe and McGrattan (2002) point out that constraints on input financing could generate unpleasant productivity effects. To assess whether the efficiency wedge was driven by business failure during 1889-1913, we compare this wedge (left y-axis) to the inverse of number of business failures (right y-axis), as shown in Figure 3.19. We find that the economic downturns coincide with large business failures.

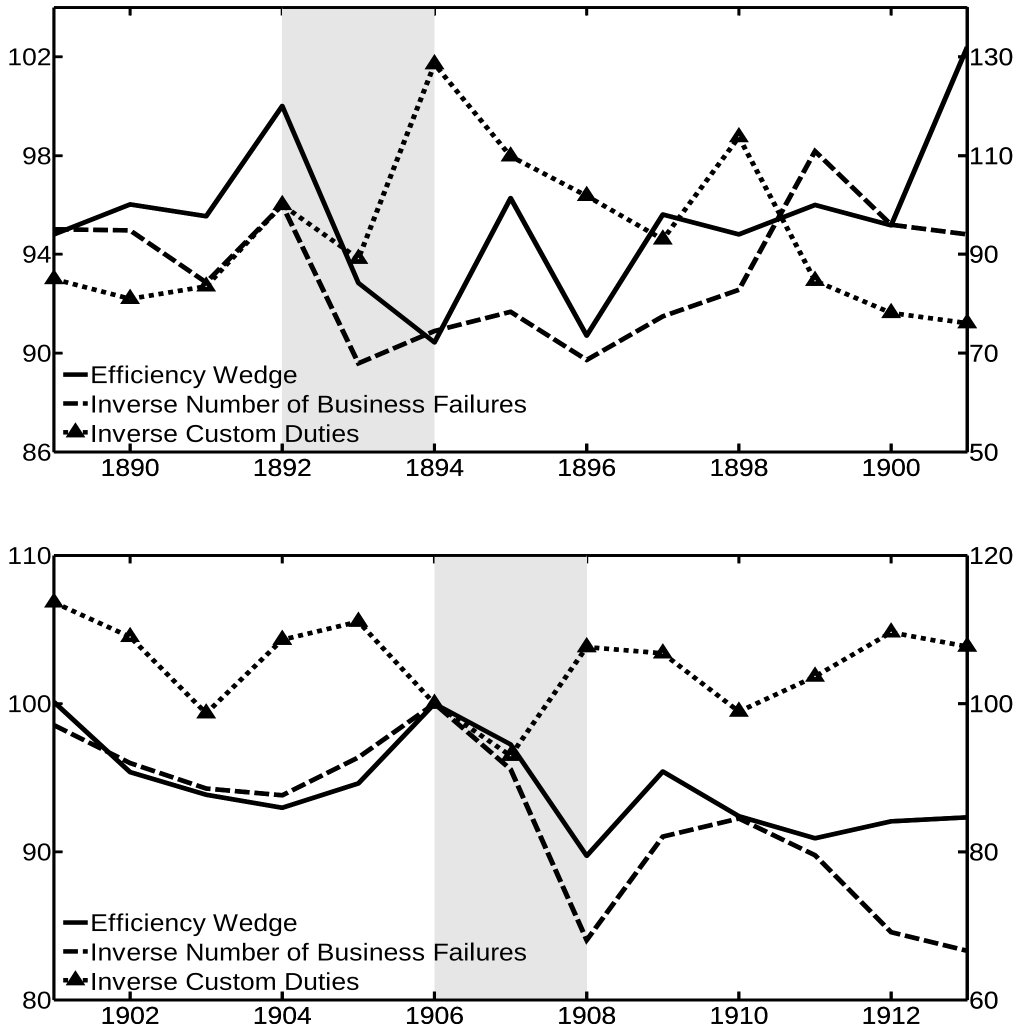
Both of the 1890s and 1907 economic slumps were associated financial stress. Since the middle of the ninetieth century, railroad investment had been a major prop to the economy (Hoffmann 1956). Investors flowed into this market and borrowed too much relying on easy credit, which eventually led to railroad over-expanding and dried up the capital streams, continuing as business failures and bank suspensions. In both recessions such financial eruptions caused credit constraints and therefore forced many firms to cut capital accumulation activities and production.

> "The declining role of the railroad was, indeed, the most significant single fact for this period and offers the most convincing explanation for the chronic hard times, particularly of the decade of the nineties." (Fel 1959, p.73).

Crucini and Kahn (1996) emphasize the importance of tariffs in economic activity. They argue that substantial material inputs are imported and therefore tariffs can results in production distortions. In their 2003 paper they demonstrate that increases in tariffs in a three-sector open economy could manifest themselves as efficiency wedges in the prototype model. Therefore we test the role of tariffs on the efficiency wedge in our two sample periods. We use the inverse of custom duties data (right y-axis), shown in Figure 3.19.[7] We can observe that most of the time the inverse tariffs and the measured TFP

[7] The data series is detrended.

Figure 3.19: Hypotheses for the Efficiency Wedge



move in opposite directions. Most notably the tariffs decline dramatically in 1894 and 1908; this tends to increase the productivity and output so the tariffs fail to explain the productivity drop in the recession. It implies that tariffs are not a likely factor explaining the efficiency wedge in pre-Fed period.

From the previous discussion we can conclude that during our sample periods, financial frictions could drive the efficiency wedge, particularly in the recession years. Given the importance of the efficiency wedge to the economy, models incorporating the financial market frictions, taking variable capital utilization into account, could be promising candidates that explain the real economy over the pre-WWI period.

3.4.2 Understanding the Labour Wedge

In a perfect competitive market where both households and firms take wages as given, competitive equilibrium conditions imply that the marginal rate of substitution equals the marginal product of labour. However in reality the MRS always deviates from the MPL. Shimer (2009) defines the ratio of the MRS and MPL as the 'labour wedge', as indicated in equation (3.1). Any deviations from this ratio of 1 indicate that there are distortions in the labour market.

Now we evaluate factors that may account for the variations in the labour wedge. Gali, Gertler and Lopez-Salido (2007) and Karabarbounis (2014) decompose the labour wedge into two components, the wage markup and the price markup. The wage markup represents the household side of the labour wedge and is captured by the ratio of the real wage and the MRS. The price markup stands for the fractions in the labour demand side and is denoted as the ratio of the MPL[8] and the real wage. These markups distort the labour market and therefore are inversely related to the labour wedge. Figure 3.20 reports the fluctuations of the labour wedge, the inverse of wage markup and the inverse of price markup. In accord with previous literatures, the inverse wage markup explains the most variations of the labour wedge.

Table 3.6 provides the second moment for output, the labour wedge and the markups over the period of 1889 to 1913 as a further evidence of the importance of the wage markup. The wage markup is strongly negatively correlated with both output (-0.79)

[8] $MRS = \frac{\theta c_t}{1-h_t}$, $MPL = (1-\alpha)\frac{y_t}{h_t}$.

Figure 3.20: Labour Wedge, Inverse of Wage Markup and Inverse of Price Markup

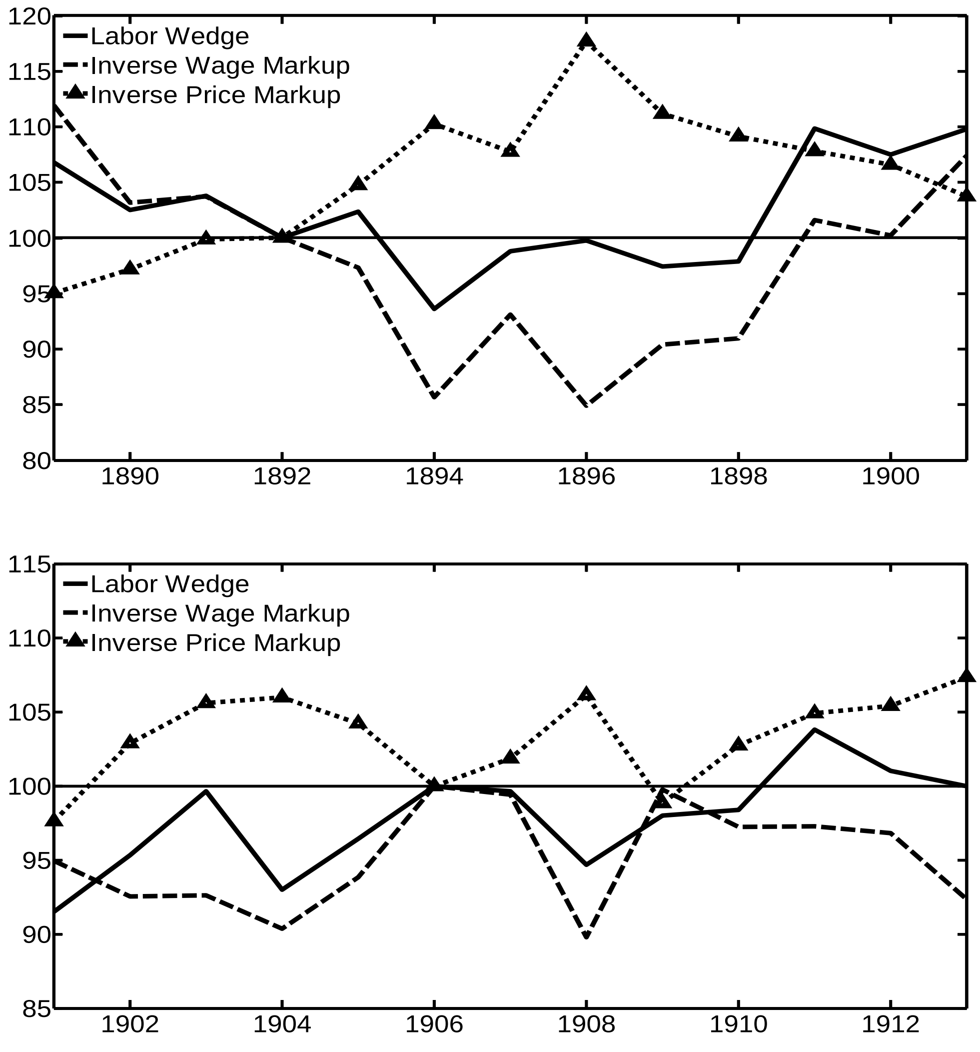


Table 3.6: Second Moments 1889-1913

Variable	Standard Deviation	Cross Correlation			
		Output	labour Wedge	Wage Markup	Price Markup
Output	5.4546	1			
labour Wedge	9.0829	0.7680	1		
Wage Markup	8.4230	-0.7861	-0.8160	1	
Price Markup	4.8708	0.0010	-0.2685	-0.3133	1

and the labour wedge (-0.81), implying that the fluctuations of output and the labour wedge are associated with the countercyclical wage markup. On the other hand, the price markup is much less volatile as the labour wedge, with a standard deviation of 4.87. Moreover, it is not correlated with output and weakly correlated with the labour wedge. These findings suggest us to focus on the labour supply side (consumer side) to explain the labour wedge.

Shimer (2009) points out that the most obvious explanation for the reduction of the labour wedge is the rise of labour and consumption taxes, as it directly affects consumer's decision about the time allocation and labour supply. However, income tax was not imposed during 1872-1913, except in 1895.

We use the exercise tax as the proxy of the consumption tax since the data of other types of consumption tax are not available. The inverse consumption tax is shown in Figure 3.23. We don't observe the feature that higher consumption tax induces lower labour wedge. Therefore, taxes do not affect the labour wedge much during the pre-1914 period.

Another explanation claims that the monetary shocks would affect the labour wedge. More specifically, prices changes induced by monetary shocks would affect the economy through intertemporal substitution of leisure and unexpected wage changes (Lucas & Rapping 1969).

We evaluate the impact of the monetary shocks on the labour wedge during the National Banking Era. Bernanke (1995) points out that banking panic leads to increases in currency-deposit ratio which is negatively related to money multiplier. Therefore we use the U.S. money multiplier as a measure of the monetary disturbance. The multiplier is represented as the ratio of aggregate broad money (M2) over base money (M0). Figure 3.23 illustrates that the movement patterns of the money multiplier is quite similar to that of the labour wedge, especially for the first sample period. It displays a dramatic decline in the money multiplier in both recession years, implying that it could be a convenient explanation as it coincides with the decline of the labour wedge.

Both the 1893 and 1907 recessions were associated with banking panics. The Sherman Silver Purchase Act, which was passed in 1890, mandated that the government had to purchase increasing amounts of silver each month, which induced the public panic due to the belief that the U.S. would not be able to maintain a gold standard of payments. Furthermore, the collapse of the railway industry led to a stock market crash, which brought on pessimism and bank runs, causing dramatic declines in the money supply. The panic happened again in 1907. The failure of F.Augustus Heinze's stock manipulation scheme to corner the stock of United Copper Company led to the collapse of the share price of the United Copper Company. A bank run was triggered by the announcement that the National Bank of Commerce would not act as a clearing agent for Knickerboker Trust Company as the president was reported to have been involved in Heinze's copper corner. As a result, the money supply decreased significantly.

The U.S. banking system over 1863-1913 was characterized as the 'the National Banking Era' during which time it had no central bank and no 'lender of last resort', reflecting the weakness of the U.S. banking structure. The monetary stringency led to output drops and triggered the recessions, because there is no reliable way to expand the money supply. It is clear that in the recessions MRS drops dramatically because consumers dislike working during economic downturns (Shimer 2009).

Figure 3.21 presents the detrended nominal wage and GNP deflator which is used as the indicator of the price level. Figure 3.22 shows the time series of the corresponding real wage and the MRS over the two sample periods. The real wage (in manufacturing industries) is around 11 percent and 7 percent above the MRS in 1894 and 1908, implying substantial wage markups.

Notably the behaviour of the real wage is different in these two recessions. From Figure 3.21 we can observe that the depression of the 1890s is a deflationary period and any monetary contractions would impose more serious deflationary pressure. As firms and industries had undergone many striking threats in late 19th century, they were unlikely to cut the nominal wages (Hanes 1993). Sundstrom (1992) also stresses that workers' resistance to reduce their wage was one culprit of the sluggishness of nominal wage adjustment in the 1892-1894 recession. One of the most outstanding strikes was the May Day strike of 1886. Therefore over this period the nominal wage is relatively sticky compared to the change of price, as indicated in Figure 3.21. Real wage slightly declines in 1983, whereas in 1894 it increases, inducing a huge gap between the real wage and the MRS. For this period, the wage stickness intensifies the effects of the negative monetary shock on the labour wedge.

On the other hand, during the period of 1901 to 1913, prices show a persistent upward trend, which could be the result of increasing gold stock (Friedman & Schwartz 1963). Moreover, Figure 3.22 shows different behaviour of the real wage in 1901-1913 compared with the previous decade. Particularly, during the 1906-1908 downturn the real wage decreases continuously. The real wage is declined as a result of the rise in inflation and the relative stickness of the nominal wage.

Figure 3.21: Nominal Wage and GNP Deflator

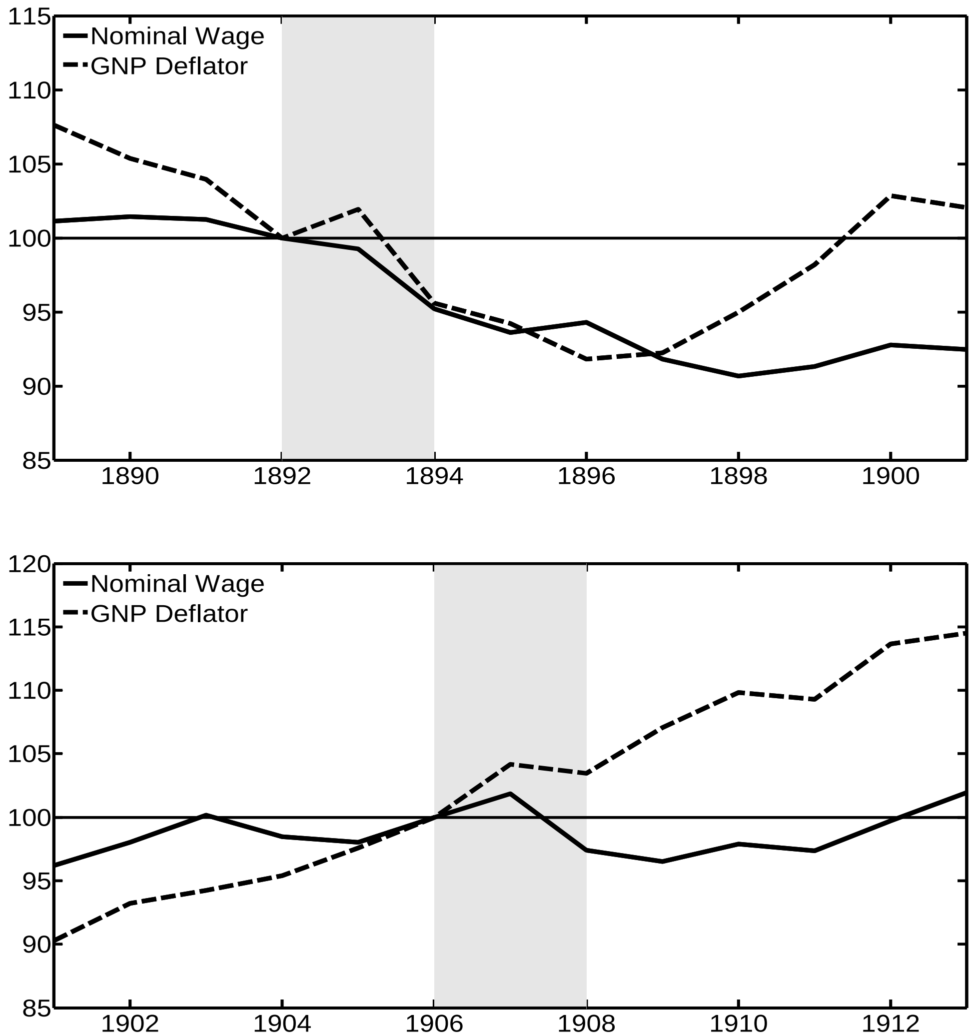
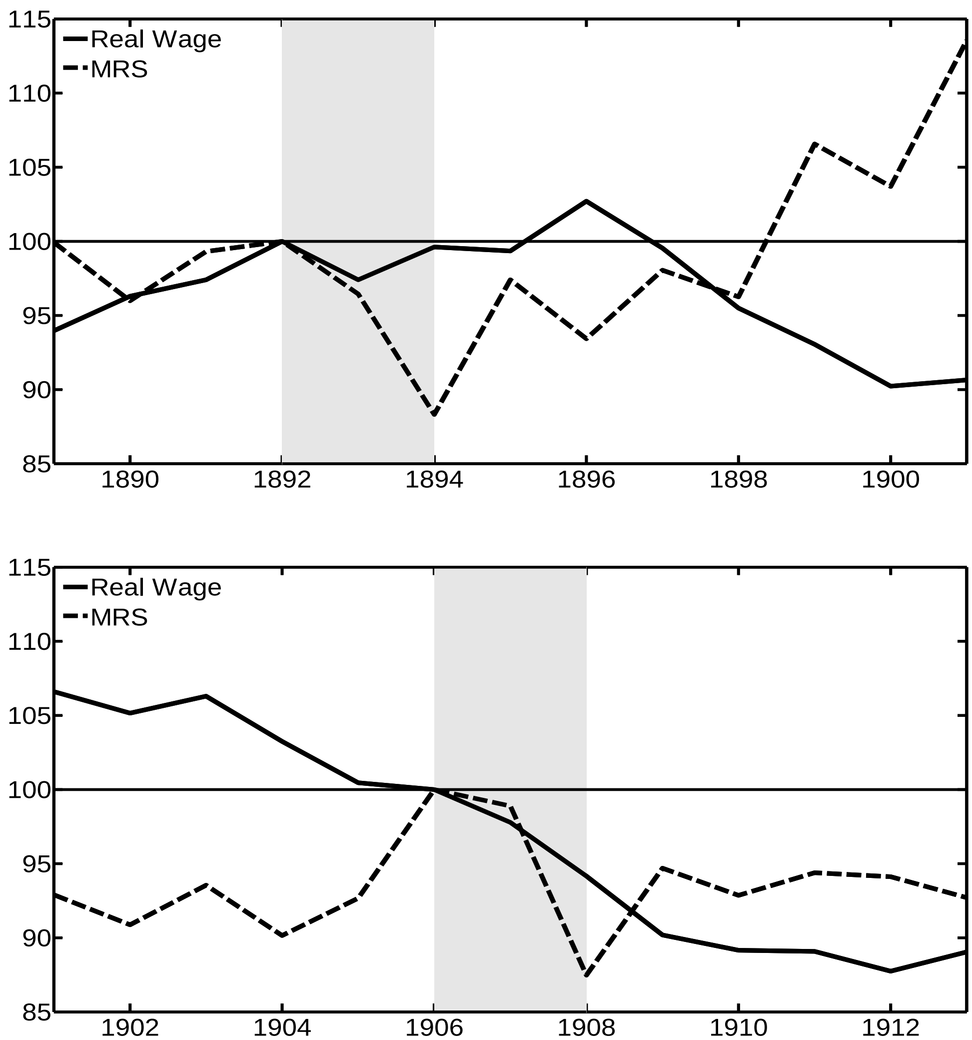


Figure 3.22: Real Wage and MRS



Cole and Ohanian (2004) emphasize that the cartelization and labour unions could result in markups over the competitive wage. We use union membership as a measure of the strength of the labour unions. Stronger labour bargaining power allows workers to increase their wage above the market-clearing level (Cole & Ohanian 2002) and therefore worsen the labour wedge. Figure 3.23 displays the fluctuations of the inverse of union membership. It may partly explain the fluctuations of the labour wedge for some periods, particularly for 1892-1894. Moreover, the slight decline of the strength of the labour union from 1907 coincides with the failure of the 1907 Mesabi Range Strike. The Mesabi Range Strike was the first organized strike on the Iron Range, motivated by dangerous working conditions and low wages.[9]

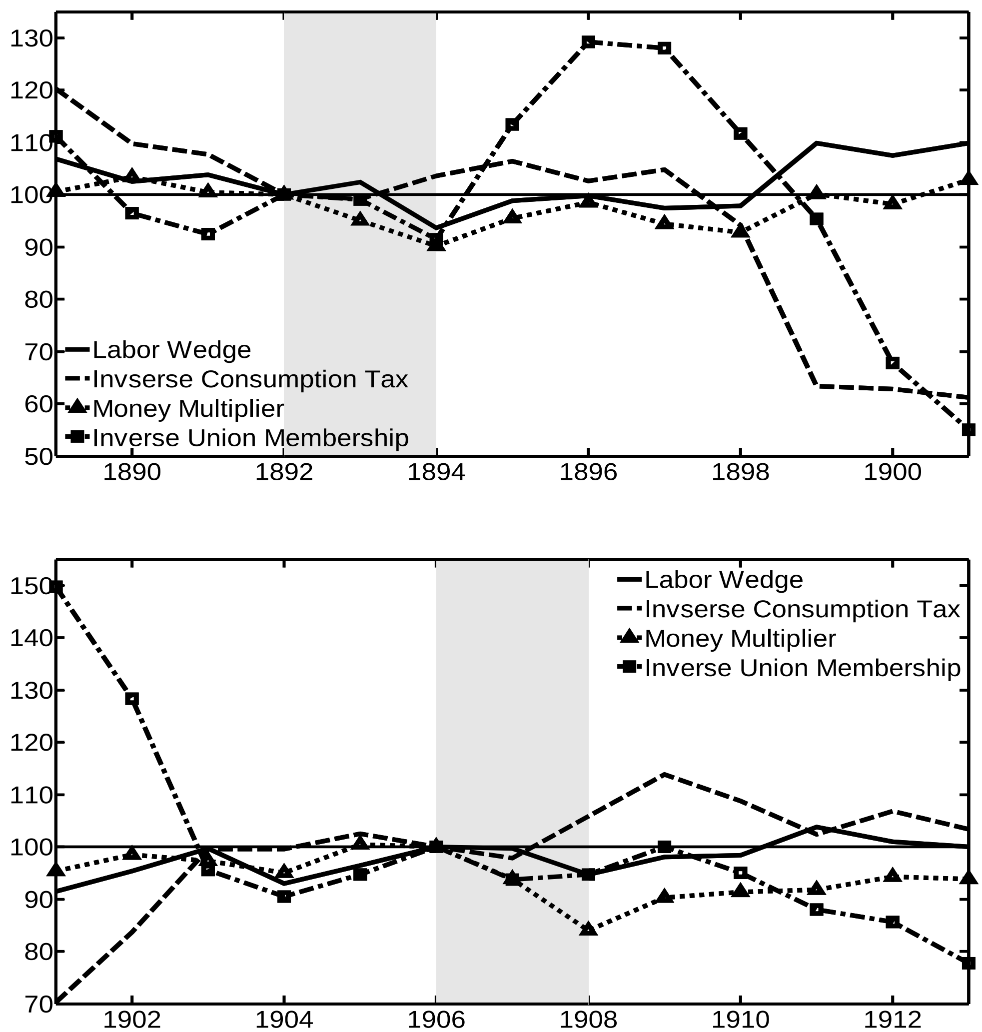
From the above discussion we conclude that monetary shock is the most likely driving factor of the labour wedge as it could generate a gap between the marginal rate of substitution and the marginal product of labour.

3.5 Conclusion

We conduct the Business Cycle Accounting exercises on U.S. data for the cyclical episode from 1889 to 1901 and from 1901 to 1913 to figure out the distortions that are primarily responsible for the economic fluctuations, particularly the 1893 and 1907 recessions. We find that the efficiency wedge alone almost accounts for the fluctuations of output and investment, and the labour wedge plays a secondary role. The movement of hours is mainly affected by the labour market frictions. The investment and government consumption wedge drive these variables to the 'wrong' directions.

[9] This unsuccessful strike was mainly due to the strikebreakers hired by the Oliver Iron Mining Company.

Figure 3.23: Hypotheses for the Labour Wedge



The BCA approach provides useful insight for researchers as it aims to find out the channel for the transmission of shocks to the economy and therefore allows them to identify the promising class of theories investigating the pre-WWI period. Our results imply that any models attempting to replicate the economic behaviour of this period should consider the market frictions that could manifest themselves as the efficiency wedge and the labour wedge in the prototype model. We compare the measured efficiency wedge with number of business failures and, find that financial market frictions may be a possible candidate that deteriorate the efficiency wedge. To understand the labour market frictions, we need to focus on the demand side of labour, that is, the discrepancy in the MRS and the real wage. Our results show that it could be attributed to the monetary shocks.

Appendix 3.A Data Sources

This Appendix provides the details of source and construction of the data used in this paper. All data are annually for the period 1889-1913 unless otherwise stated.

3.A.1 Original Data

O.1. Gross National Product, Commerce Concept. Millions of 1929 Dollars. Source: Kendrick (1956), P.290, Table A-IIa.

O.2. Gross National Product, Commerce Concept. Millions of Current Dollars. Source: Kendrick (1956), P.296, Table A-IIb.

O.3. Manhours, Total. Millions. Source: Kendrick (1956), P.311, Table A-X.

O.4. Total Consumption Expenditures, Commerce Concept. Billions of 1929 Dollars. Source: Kendrick (1956), P.290, Table A-IIa.

O.5. Gross Private Domestic Investment, Commerce Concept. Millions of 1929 Dollars. Source: Kendrick (1956). P.290, Table A-IIa.

O.6. Consumption Durables. Millions of Current Dollars. Source: Historical Statistics of the United States (2006), P.3-270, Series Cd411.

O.7. Resident Population, Total. Thousand. Source: Historical Statistics of the United States (2006), P.1-28, Series Aa7.

O.8. Capital Utilization Rate. 1967-1983. Source: Board of Governors of the Federal Reserve System Database, G17.

O.9. Real Gross National Product. 1972 Dollars. Source: Hall and Gordon (1986), P.781, Table 1.

O.10. Trend Real Gross National Product. 1972 Dollars. Source; Hall and Gordon (1986), P.781, Table 1.

O.11. Stock Price Index. Source: Cowles (1939), Common Stock Indexes.

O.12. Custom Duties. Thousand Dollars. Source: Annual Report of the Secretary of the Treasury, 1929, P.428.

O.13. Exercise Taxes. Thousand Dollars. Source: Historical Statistics of the United States, Colonial Times to 1970, p.1108, Series 364-373.

O.14. Aggregate Broad Money M2, Friedman and Schwartz. Source: Historical Statistics of the United States (2006), P.3-604, Series Cj45.

O.15. High-Powered Money M0. Source: Historical Statistics of the United States (2006), P.3-631, Series Cj141.

O.16. Nominal Hourly Earnings, Manufacturing. Source: Historical Statistics of the United States (2006), P.2-270, Series Ba4314.

O.17. Union Members, Friedman. Thousand. Source: Historical Statistics of the United States (2006), P.2-336, Series Ba4789.

O.18. Total Factor Productivity, Commerce Concept. Source: Kendrick (1956), Table A-XXII.

O.19. Yield on Corporate Bonds. Source: Hall and Gordon (1986), p.781, Table 1.

O.20. Commercial Paper Rate. Source: Hall and Gordon (1986), p.781, Table 1.

O.21. Number of Business Failures. Source: Historical Statistics of the United States (2006), P.3-550, Series Ch411.

3.A.2 Constructed Data

C.1. GNP Deflator=O.2./O.1.

C.2. Net Factor Payments=0.005×O.1.

C.3. Real Per Capita Output=O.1./O.7./1000

C.4. Real Per Capita Investment=(O.5.+O.6./C.1.+C.2.)/O.7./1000

C.5. Real Per Capita Consumption=(O.4.×1000 - O.6/C.1.)/O.7./1000

C.6. Per Capita Hours Worked=O.3./O.7./1000

C.7. Real Custom Duties=O.12./C.1.

C.8. Real Exercise Taxes=O.13./C.1.

C.9. Money Multiplier=O.14./O.15.

C.10. Capacity Utilization=O.9./O.10.

C.11. Real Wage=O.16./C.1.

C.12. Interest Rate Spread = O.19. - O.20.

Chapter 4

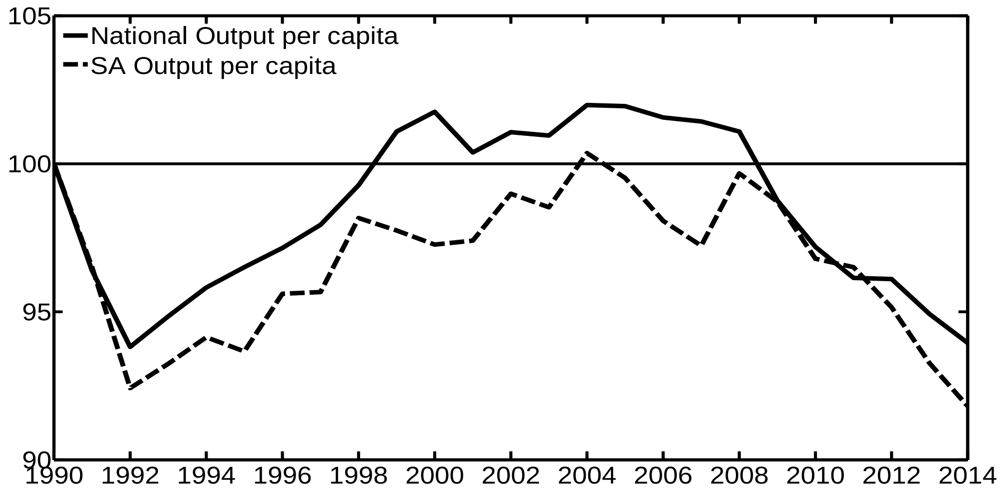
Tracing the Sources of South Australian Economic Slumps

4.1 Introduction

Australia's regional economy has been regarded as an important determinant of economic development within the country (Beer et al. 2003). O'Nail, Neal and Nguyen (2004) illustrate that South Australia's (SA) economic growth has lagged behind the rest of Australia since 1990. Over the past two decades the average annual growth rate of SA's real gross state product (GSP) per capita was 1.96 percent. Australia on the other hand underwent stronger and faster growth during 1990-2014. Moreover, in terms of level, GSP per capita in SA is consistently below its national level. Particularly, during the recession of early 1990s, South Australia fared one of the worst as the result of the State Bank collapse.

Figure 4.1 shows per capita GSP and per capita GDP which are detrended by their av-

Figure 4.1: Indexes of Real GSP and GDP (1990=100)



erage long-run growth rates from 1990 to 2014. It is easily observed that SA's economic performance is feeble relative to the Australian economy.

There are three major economic slumps in SA, including early-1990s, the Asian Financial Crisis, Global Financial Crisis and its subsequent years. In all of these three slumps not only the economic contractions are more severe in SA, but also the recoveries are more sluggish. Notably from 1990 to 1992, output in SA declines more sharply than GDP and the gap widens from 1998. From 2008 the economy enters a long slump, it is adversely affected by the Global Financial Crisis and then hit by another recession in 2012. The overall under-performance of SA against Australia appeals for more attention of government to policy design. It is imperative to understand the cyclical behaviour of SA economy.

What accounts for the fluctuations of the economy and what factors caused the recessions and recoveries since 1990? This paper addresses these questions in the context of a neoclassical model of the business cycle. In particular, we apply the accounting method developed by Chari, Kehoe and McGrattan (2007) (CKM) to decompose the economic fluctuations into its sources from 1990 to 2014. One major merit of the CKM method is that it allows four time-varying distortions in a model simultaneously. In a standard real business cycle model the only primitive shocks that could affect the economy are technology shocks.

In this approach, frictions appear as four 'wedges' in the first order conditions and prevent the economy from its best outcome as in perfect competitive market. These wedges are: the efficiency wedge, measured as the Solow residual, is the deviation of actual production from optimal production implied by the growth model; the labour wedge, which drives a wedge between the marginal product of labour (MPL) and the marginal rate of substitution (MRS) between consumption and leisure; and the investment wedge which distorts the Euler equation. These wedges at face value act as taxes on labour and investment income. The fourth wedge, the government consumption wedge, is defined as the sum of the government spending and net export. The CKM approach provides useful insight into government policies as it helps policy makers to identify the transmission mechanisms through which the external shocks affect the economy and formulate the corresponding policies that help reducing these frictions. If there are more transmission channels then it also pins down the primary one (Chakraborty 2006).

Our main finding is that the efficiency wedge is the primary driving force of South Australian economic fluctuations. The government consumption wedge is partly attributed to the output declines and the subsequent recoveries in early 1990s. The labour wedge may explain in part the decline in output in the recent recession and is important to labour movements. The investment wedge plays no role in the output, as it generates output that moves opposite to the observed data. However, it captures the behaviour of consumption. Although none of the wedges could be safely ignored, the efficiency wedge is of first importance in explaining the economic fluctuations in all of the episodes of our interest.

The accounting results suggest that attentions should be paid primarily to those frictions that affect the SA economy through the efficiency wedge. There are several possible candidates that might deteriorate the efficiency wedge in SA during recessions: (i) shifts of factor inputs across economic sectors associated with the structual changes in SA, (ii) the misallocation of human capital due to the collapse of automotive industry in SA, (iii) state government as a producer reduces public expenditures in health, education and infrastructure, (iv) decline in trade openness. All of these factors would impact the Solow residual and generate production deviations. In particular, in comparison with other states of Australia, South Australian infrastucture investment to output ratio and the trade openness are both overall subdued and its economic growth is also lagged behind other states.

To our knowledge, this methodology has been applied to several countries over different sample periods but not yet to regional levels. For example, CKM (2007) examine the Great Depression in the U.S. and the postwar U.S. economy. They conclude that the primitive shocks affect the U.S. economy through the efficiency wedge and labor wedge. However in SA, the labor wedge is not a driving force. Furthermore, they argue that the investment wedge does not play an important role. This finding applies in SA. Kersting (2008) studies the 1980s recession in the UK and finds that the labor-leisure distortions are the major causes of the recession. Chakraborty (2006, 2009) also investigates the Japanese and Indian economies.

In the next section we describe the framework of the accounting method, including the prototype model and description of the stochastic process governing the wedges. Section 4.3 and 4.4 present the accounting results and discussion. Section 4.5 concludes.

4.2 Framework of the Accounting Method

In this section, we describe a standard, closed economy neoclassical growth model with four wedges: the efficiency wedge, often explained literally as productivity shocks; the labour wedge and the investment wedge, which look like labour income and investment taxes; and the government consumption wedge, which is defined as government consumption plus net export. These wedges capture the deviations between theory and the data.

4.2.1 The Prototype Model

The economy comprises N_t identical infinitely-lived households which grows at a constant rate g_n. The stand-in household chooses per capita consumption c_t, per capita hours worked h_t, and per capita capital k_{t+1} to maximize his life time utility

$$\max_{c_t, h_t, k_{t+1}} E_0 \sum_{t=0}^{\infty} \beta^t U(c_t, 1-h_t) N_t,$$

subject to the budget constraint

$$c_t + (1+\tau_{xt})x_t = (1-\tau_{ht})w_t h_t + r_t k_t$$

and capital accumulation law

$$(1+g_z)(1+g_n)k_{t+1} = (1-\delta)k_t + x_t,$$

where x_t denotes per capita investment, k_t is per capita capital stock, w_t is real wage, r_t stands for capital rental rate. τ_{lt} and τ_{xt} are tax rates on labour income and investment, respectively. β is the discount factor and δ is the depreciation rate on capital stock.

Firms maximize profit by choosing labour and capital demand

$$\max_{k_t,h_t} y_t - r_t k_t - w_t h_t,$$

subject to the technology

$$y_t = F(k_t, z_t h_t),$$

where z_t denotes productivity shocks. The long-run average growth rate of the technical progress is g_z and is assumed to be constant over time.

Then the economy is characterized by the following first order conditions: (4.1) the intratemporal labour-consumption trade off, (4.2) the consumption Euler equation and budget constraints: (4.3) the firm's production function, (4.4) the resource constraint faced by the economy.

$$\frac{u_{ht}(c_t, 1-h_t)}{u_{ct}(c_t, 1-h_t)} = (1-\tau_{ht})F_{ht}(k_t, z_t h_t), \tag{4.1}$$

$$\beta E_t u_{ct+1}(c_{t+1,} 1-h_{t+1})[(F_{kt+1}(k_{t+1,} z_{t+1}h_{t+1}) + (1-\delta)(1+\tau_{xt+1})] = (1+g_z)(1+\tau_{xt})u_{ct}(c_t, 1-h_t), \tag{4.2}$$

$$y_t = F(k_t, z_t h_t), \tag{4.3}$$

$$y_t = c_t + x_t + g_t, \tag{4.4}$$

where u_{ct}, u_{ht} and F_{kt}, F_{ht} refer to the first derivatives of the utility function and production function with respect to its argument like consumption, labour and capital. g_t is the sum of government consumption and net export. Note that in this model, the efficiency wedge is $z^{1-\alpha}$, it is essentially the measure of total factor productivity. The labour wedge and the investment wedge are defined as $1-\tau_{ht}$ and $\frac{1}{1+\tau_{xt}}$. They capture the deviation between data and the first order conditions in a frictionless economy. In other words, these wedges interfere with the consumer and firm's optimal decisions, just like frictions do. The government consumption wedge equals g_t.

Chari, Kehoe and McGrattan (2007) demonstrate that various detailed models with different types of frictions can generate the same equilibrium allocations as the prototype model with one or more wedges. For example, input-financing frictions manifest themselves as the efficiency wedges. A monetary model with sticky wages maps into the labour wedges (Bordo et al. 1997). Bernanke et al. (1999) model with credit market frictions maps into the investment wedges in the prototype model.

4.2.2 Application to South Australia

We apply the accounting method to South Australia (SA) to account for the economic fluctuations during the period 1990-2014. We need to specify the functional forms of the utility function and the technology. The household preference is described by

$$u(c_t, 1-h_t) = logc_t + \theta log(1-h_t),$$

where θ is time allocation parameter. The production function is a Cobb-Douglas

$$y_t = k_t^{\alpha}(z_t h_t)^{1-\alpha}.$$

These functional forms are widely used in business cycle literature.

Data from SA covers the period 1990-2014. The original data source is the Australian Bureau of Statistics. As we focus on a state-level economy, output is defined as the gross state product.[1] The raw data are transformed into per capita data and detrended by g_z. The details on the construction of the data are shown in the Appendix.

The wedges are measured from the model and data. To solve the model we need to assign the parameter values. The labour share $1-\alpha$ is computed in two alternative ways: (a) unambiguous labour income divided by GSP net of the ambiguous categories: compensation of employees divided by GSP net household net mixed income and indirect taxes, (b) compensation of employees divided by total factor income of all industries. Both methods give 0.54 of labour share.

The population grows at a rate of 0.65 percent which is its average annual growth rate during the target period. Similarly, the long-run average growth rate of per capita output is 1.96 percent; therefore we set g_z to 1.96. For other parameters we are not able to compute from historical data and models directly as the steady state value of the wedges are unknown in this step. Therefore we use existing business cycle literature parameter values on yearly basis, as displayed in Table 4.1.

Given these parameter values, we can compute the steady state values of the four wedges. As the efficiency wedge, the labour wedge and the government consumption wedge could be computed directly from equations (4.1), (4.3) and (4.4) once the parameter values are assigned, the steady state values equals are set to equal their average values. This cannot be applied to the investment wedge as equation (4.2) involves expectations. For the steady state level of the investment wedge τ_x we use steady state expression of this equation. Therefore,

$$\tau_x = \alpha\overline{(\frac{y}{k})}\frac{1}{\frac{g_z}{\beta} - (1-\delta)} - 1,$$

[1]The most reliable measure of the economic activity is GSP and it is only available on an annual basis.

Table 4.1: Parameter Values

Parameters	Values
Net technological progress growth g_z	0.0196
Net population growth g_n	0.0065
Capital share α	0.4600
Discount factor β	0.9500
Time allocation parameter θ	2.2400
Depreciation rate δ	0.0500
Steady state value of efficiency wedge z	1.1997
Steady state value of labour wedge τ_h	-0.1104
Steady state value of investment wedge τ_x	-1.2761
Steady state value of government consumption wedge g	0.2593

where $\overline{(\frac{y}{k})}$ is the average output-capital ratio over the period of our interest.

The construction of the efficiency wedge, the labour wedge and the government consumption wedge is straightforward, as described above. For the investment wedge we assume that it follows first-order autoregressive process

$$s_{t+1} = P_0 + Ps_t + \varepsilon_{t+1}, \varepsilon_t \sim N(0_4, V),$$

where $s_t = [log(z_t), \tau_{ht}, \tau_{xt}, log(g_t)]'$ and ε_t is a vector of independently and identically distributed shocks with zero mean and covariance matrix V. Q is a lower triangular matrix and is defined such that $V = QQ'$. We estimate P_0, P and Q using the maximum likelihood estimation.

For this purpose, we log-linearize the system of the equations and apply the undetermined coefficients method. The state-space form of the model can be written as:

$$X_{t+1} = AX_t + B\varepsilon_{t+1},$$

$$Y_t = CX_t + \omega_t,$$

Table 4.2: Parameters of Vector AR(1) Stochastic Process

Coefficient Matrix P on Lagged States				Coefficient Matrix Q where $V = QQ'$			
−0.4972 (2.3346)	1.0880 (2.2472)	2.4232 (4.9824)	0	−0.0217 (0.0090)	0	0	0
−0.9990 (2.1877)	1.4744 (1.5843)	1.2401 (3.7346)	0	−0.0284 (0.0356)	−0.0223 (0.0083)	0	0
−0.0060 (0.5812)	0.1444 (0.3995)	1.1202 (1.0023)	0	0.0017 (0.0164)	0.0108 (0.0089)	0.0076 (0.0121)	0
0	0	0	0.7767 (0.1373)	0	0	0	0.1036 (0.0399)

where $X_t = [log(k_t), log(z_t), \tau_{ht}, \tau_{xt}, log(g_t), 1]'$ and $Y_t = [log(y_t), log(x_t), log(h_t), log(g_t)]$.[2] ω_t refers to the measurement error.

The matrix A summarizes the coefficients relating k_{t+1} to X_t, which includes the matrix P_0 and P. The matrix C consists of coefficients linking Y_t to X_t. Note that as we are not focusing on the primitive shocks that affect the economy, it is not necessary to make structural assumptions of the primitives ε_t and the wedges need not to be orthogonal (Amand 2013). The estimated stochastic process for the wedges is reported in Table 4.2.

Once we get the stochastic process of the wedges we can obtain the investment wedge. Next, in order to evaluate the contribution of each wedge to the fluctuations of the economy, we feed the wedges one by one into the model and compare which model could best replicate the data. Note that if we include all of the four wedges in the model, we can exactly replicate the data given by way of our data construction.

[2] X_t contains capital and four wedges. Y_t includes the observed or easily obtained variables.

4.3 Results and Discussion

4.3.1 Stylized Facts

In Australia, the fiscal year starts on 1 July and ends on 30 June. For example, data in 1990 covers information from 1989:III to 1990:II.

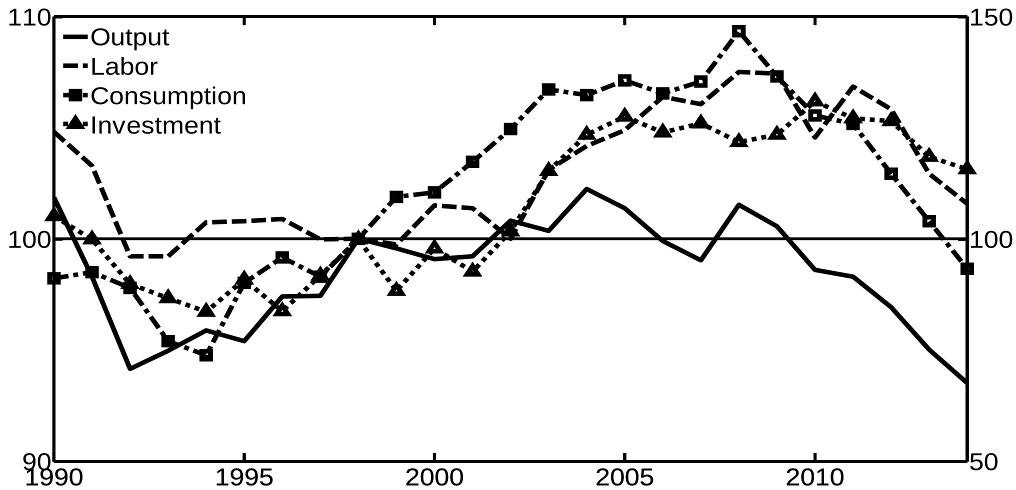
We start with dating recessions since there are no official dates for business cycles in South Australia. We define a recession as a period of negative economic growth for two or more consecutive quarters. Our analysis focuses on the following recession episodes and the subsequent recoveries: 1990:IV to 1991:III, 1998:IV to 1999:II, 2007:III to 2008:I and 2012:II to 2012:IV.[3] During these episodes SA experienced at least three consecutive quarters of negative economic growth according to the aggregate demand data.[4]

Figure 4.2 shows the per capita detrended macroeconomic variables. Output, labor and consumption are ploted on the left y-axis, investment is shown on the right y-axis. In this figure, all data are normalized to equal 100 in 1998, one of the peak years before the recessions. In the early-1990s the South Australian economy experienced a severe economic distress, as a consequence of the collapse of the State Bank. The recession began in mid 1990 and lasted for several months. We can observe from the graph that in this recession output declines by approximately 7.7 percent below its 1990 level. Then the economy recovers in 1992 and experiences a record period of economic growth since early 2000s. Dowrick (2001) points out that there was a boost in productivity during this period. This might be the result of microeconomic reform, new information and communication technologies, and higher capital intensity (Hancock & Hsieh 2006).

[3] We treat 2008-2012 as a big economic slump. The trends and business cycles in SA and Australia are shown in the Appendix.

[4] We skip the recessions of 1998:I to 1998:II and 2013:III to 2013:IV which are relatively short-lived.

Figure 4.2: Macroeconomic Aggregates 1990-2014



The economy slows down in the wake of the Asian Financial Crisis. Figure 4.2 shows that output slightly declines since 1998. In 1999 investment is more than 10 percent below its 1998 level. Nevertheless, it shows relatively strong resilience to the crisis, demonstrating the benefits of the structural changes and the efficiency of the implementation of government policies. In 2000, South Australian government introduced the First Home Owner Grant to stimulate building and construction activity. Moreover, as a result of major investment projects such as a one billion expansion of equipments and machinery used in Holden's production, investment has surged since 2001.

In 2012, the state went into a recession. Halim et al. (2013) report that it is the biggest downturn since the early-90s recession, brought on as a result of a large decline in lower public sector capital expenditure. Building and construction activities soften. In fact, per capita GSP shows continuous drops since 2008. As indicated in Figure 4.2, the economic performance in 2014 is even worse than that in 1992.

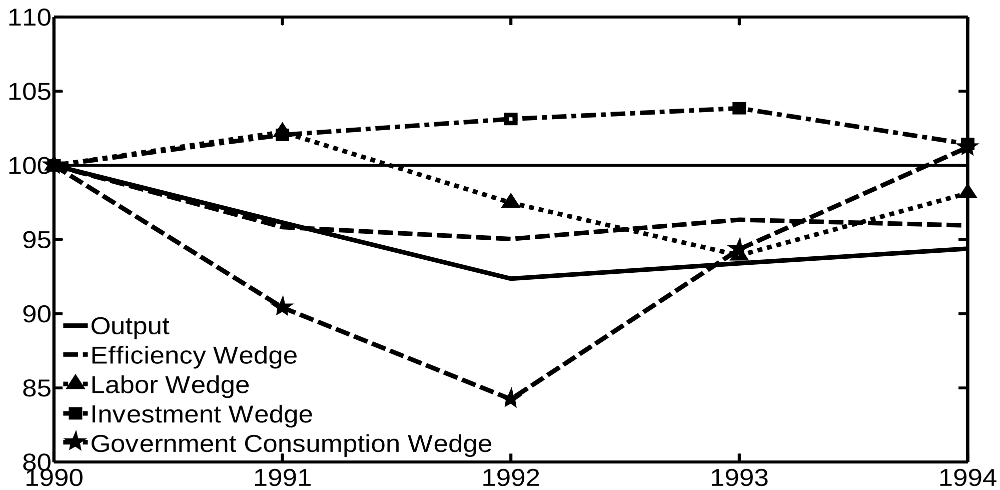
In the following three subsections, we show the observed wedges computed using the method described in section 4.2 as well as the decomposition results for the three recessions in South Australian economy. Once we identified the primary transmission channel (wedge) though which the shocks affect the economy, we are able to narrow down the driving forces behind these recessions and recoveries.

4.3.2 The Early 1990s Recession

Figure 4.3 illustrates the measured efficiency wedge, the labour wedge, the investment wedge and the government consumption wedge from 1990-1994. All variables are set to equal 100 in 1990. This figure depicts that over this sample period, the efficiency wedge shows a very similar pattern of movements to output. In 1992, the efficiency wedge is 4.97 percent below the trend observed in 1990. The labour wedge fails to capture any features of the recession and recovery. The investment wedge shows countercyclical behaviour. In fact, the movements of the investment wedge are quite smooth relative to other wedges. Therefore frictions that captured by the labour wedge or investment wedge are not driving forces of this cyclical episode. The government consumption wedge falls by 15.77 percent during 1990-1992.

Next, we evaluate the marginal effects of these wedges to identify the wedge that accounts for the most of the economic fluctuations. For this purpose, we include only one wedge in the model at a time while keeping the other wedges 'inactive'. Figure 4.4 shows output decomposition results. Over the period of 1990-1994, output due to the efficiency wedge 'overlaps' with the observed data quite well. In particular, the deterioration of the efficiency wedge is crucial to the early-1990s recession: it approximately accounts for 95 percent of output drops in 1992. Neither of the labour wedge nor investment wedge is able to correctly mimic fluctuations in terms of both cyclicity and amplitude. The investment wedge generates countercyclical and relatively flat movements. With respect to the government consumption wedge model, it generates output

Figure 4.3: Measured Wedges 1990-1994



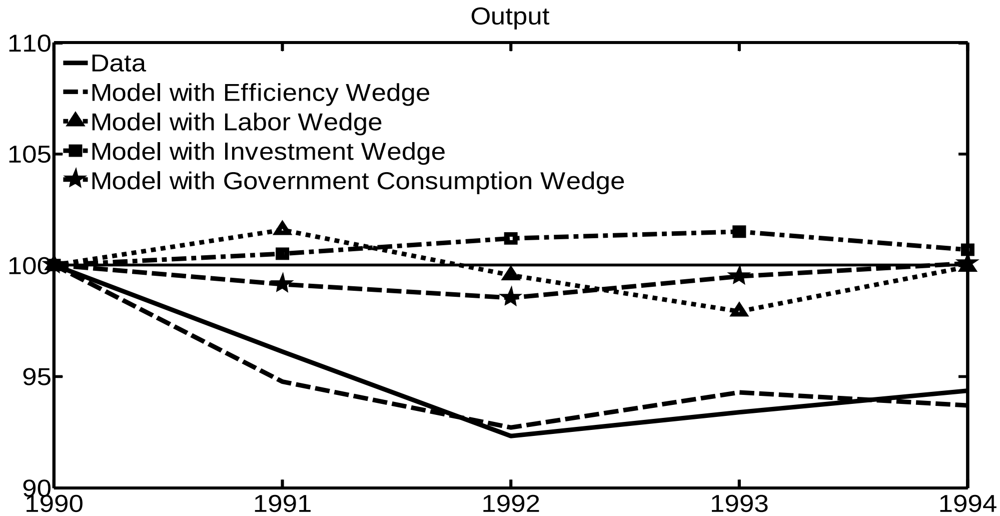
that moves to the same directions as data. However the proportion of the business cycle explained by this wedge is much smaller than that of the efficiency wedge.

Figure 4.5 depicts the development of labour, investment and consumption. The efficiency wedge plays a less role in the fluctuations of these variables compared to its importance to output. However it still accounts for larger movements of these variables than other wedges, particularly in the recession. Notably, investment due to the efficiency wedge declines more than twice of that in observed data, which is alleviated by the other three wedges. The government consumption and labour wedge may be partly responsible for the recovery of labour from 1993. The behaviour of consumption from 1992-1994 is driven by the labour and investment wedge.

4.3.3 The Asian Financial Crisis

We apply the same accounting procedure over the period of 1998-2002. All variables are scaled to equal 100 in 1998 as it is the previous peak year before the economic

Figure 4.4: Output Decomposition 1990-1994



downturns. From Figures 4.6 and 4.7 we can observe that the efficiency wedge has similar movement patterns as output in both recession and recovery periods. The economic downturn during the Asian Financial Crisis is relatively mild. The efficiency wedge predicts more output drop than the observed data. Although the investment wedge is slightly worsened at the beginning of the crisis, implying that it might be a contributor of the early recession, in general its movements are not relative to the economic performance. The condition of the labour wedge improves and drives output upward; partly offseting the excessive role of the efficiency wedge.

The decomposition results of labour, investment and consumption during 1998-2002 are shown in Figure 4.8. The movements of labour are primarily driven by the labour wedge. The efficiency wedge is almost completely attributed to the decline of investment in 1999 and is responsible for its recovery in 2001. The movements of consumption are mainly due to the investment wedge, followed by the labour wedge.

Figure 4.5: Labour, Investment and Consumption Decomposition 1990-1994

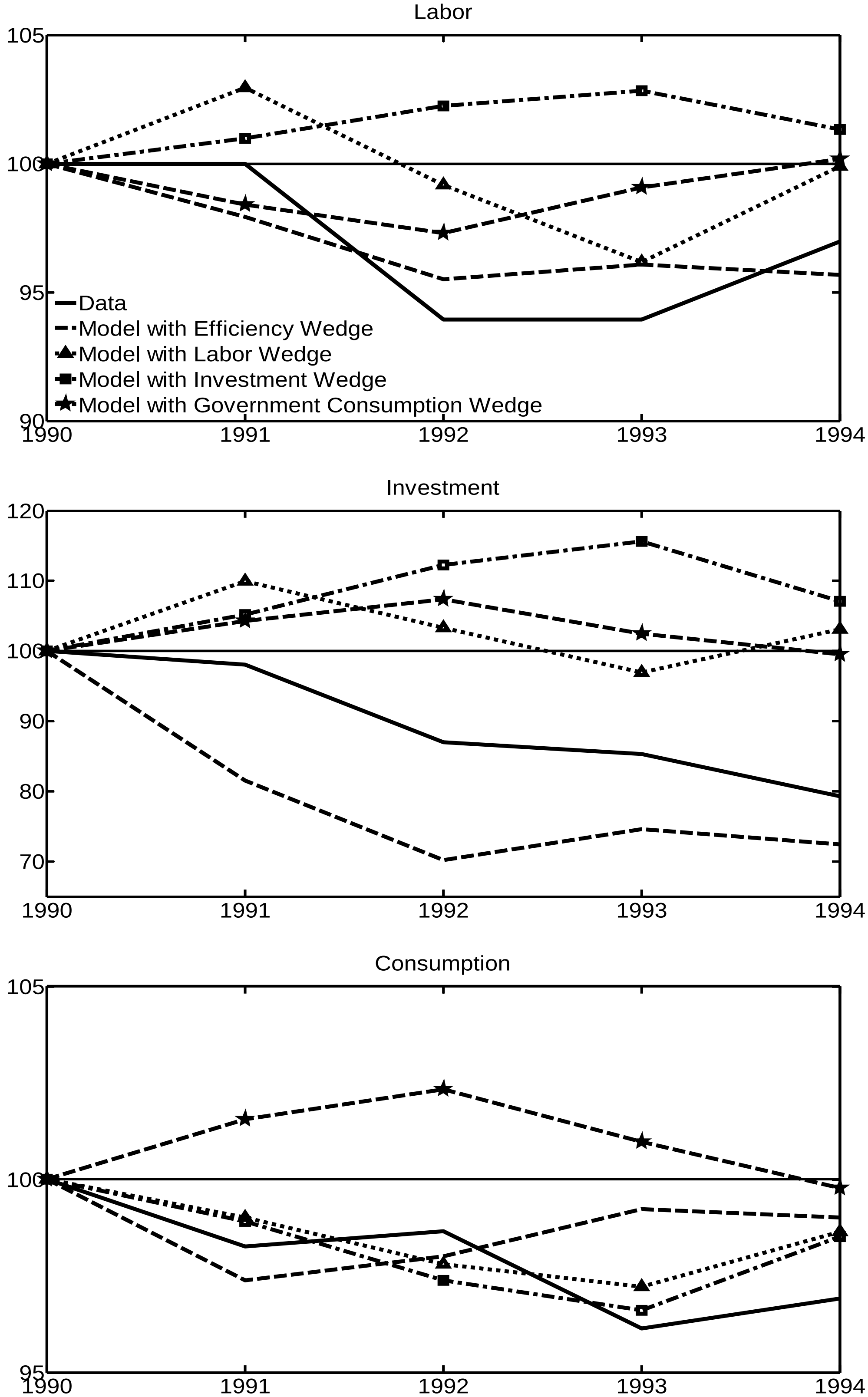


Figure 4.6: Measured Wedges 1998-2002

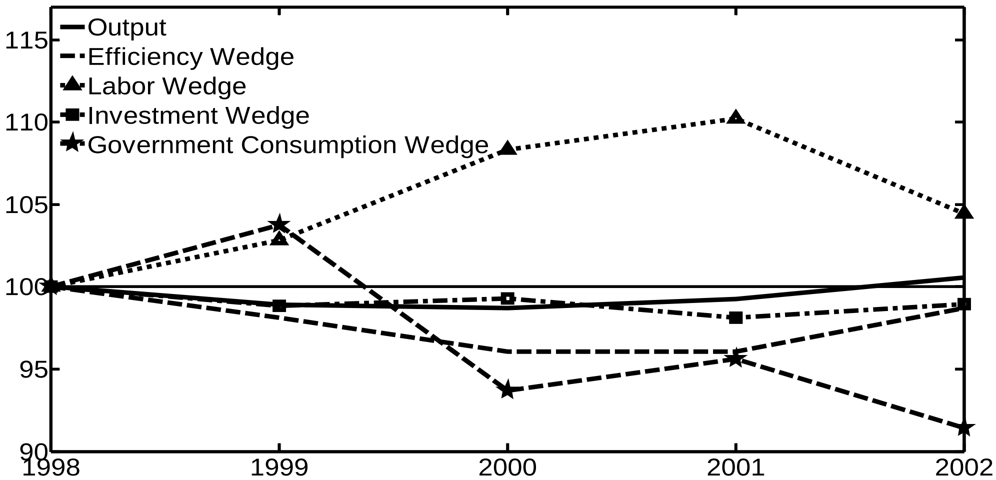


Figure 4.7: Output Decomposition 1998-2002

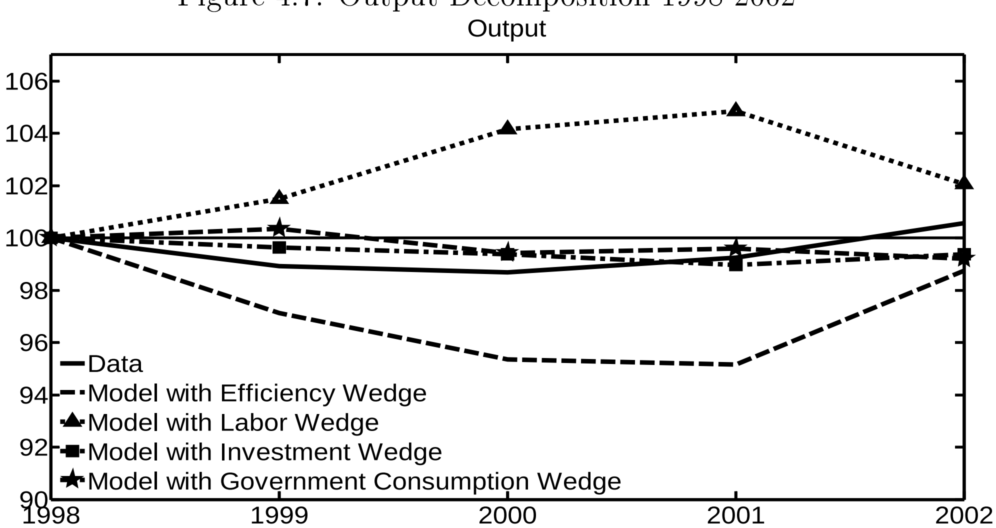


Figure 4.8: Labour, Investment and Consumption Decomposition 1998-2002

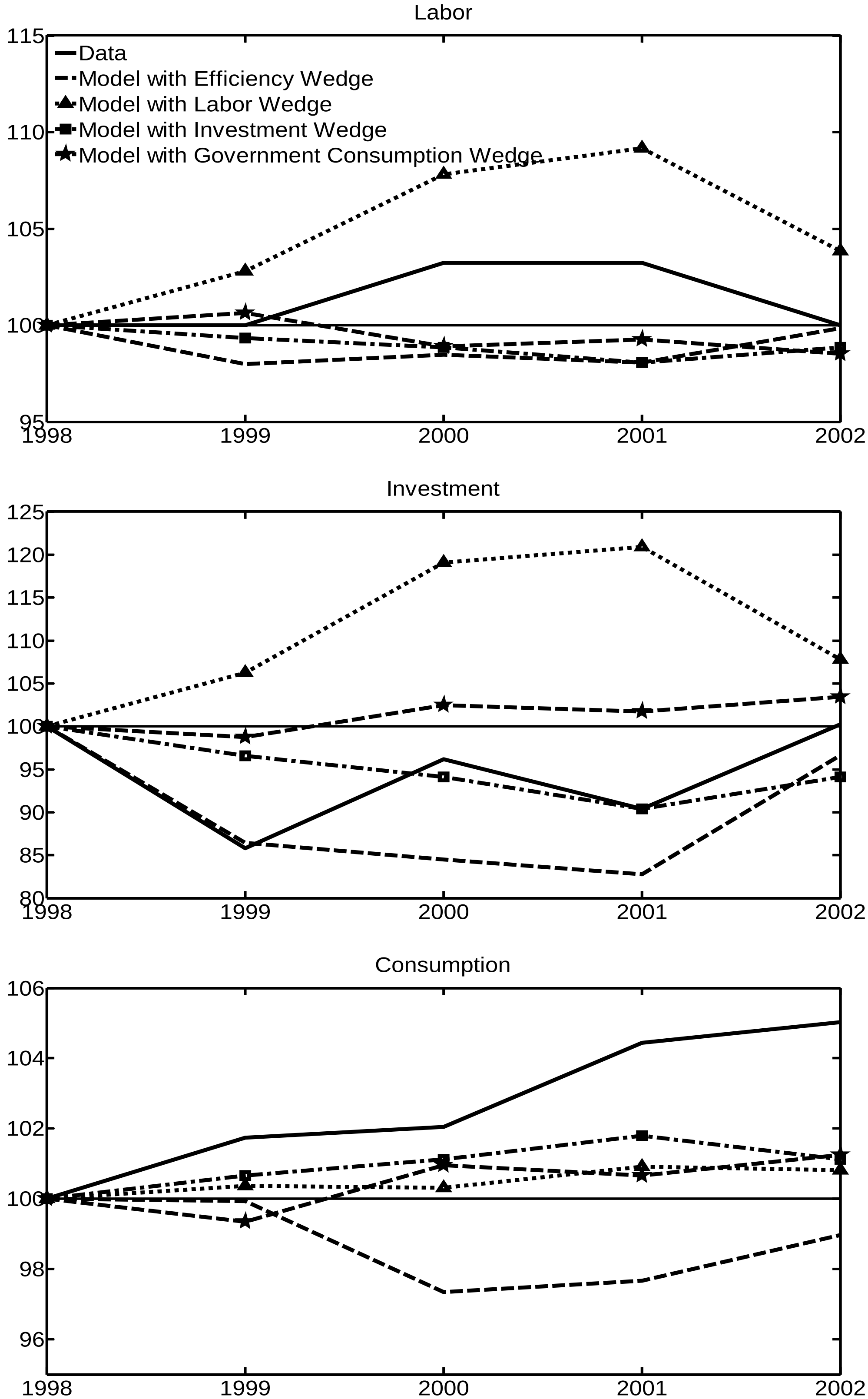
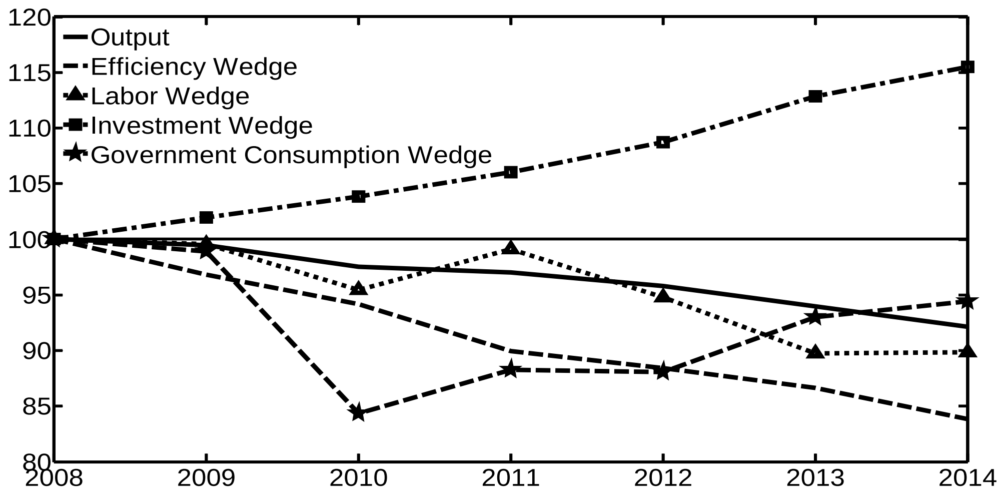


Figure 4.9: Measured Wedges 2008-2014



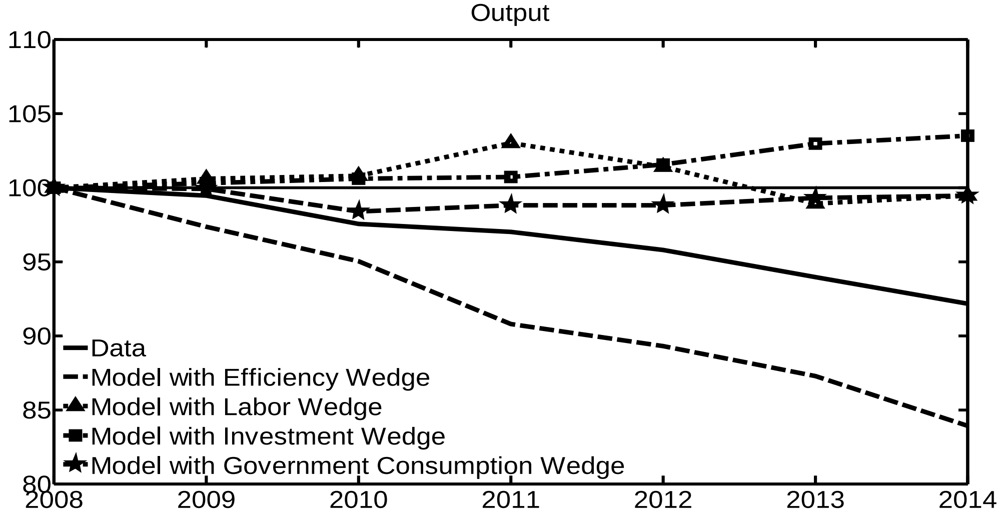
4.3.4 The Most Recent Recession

For the period of 2008-2012, all variables are nomalized to equal 100 in 2008. The measured wedges and the decomposition results are depicted in Figures 4.9 to 4.11.

The efficiency wedge declines continuously. In 2013, it is more than 15 percent below the trend level observed in 2008. Its movements are in step with that of output. The investment wedge moves in the 'wrong' direction. At first glance, the labour wedge and government consumption wedge seems conductive to the output drop from 2008 to 2010. Figure 4.10 indicates that overall the fluctuations of output are mainly driven by the efficiency wedge, followed by the government consumption wedge. However, the effects of the government consumption wedge cease since 2010. The labour wedge partly contributes to output drops in 2011-2013.

The government consumption wedge is the primary culprit for the initial decline in labour, whereas it increases investment. As shown in Figure 4.11, simulated labour due to the government consumption wedge well predicts actual data from 2008-2010.

Figure 4.10: Output Decomposition 2008-2014



Since then movements of labour could be explained by the labour wedge, and the efficiency wedge also comes into play from 2012. Investment is driven by the government consumption wedge prior to 2012, whereas the following decline in investment is attributed to the efficiency wedge. With respect to consumption, all but the government consumption wedge together accounts for its movements.

4.4 Discussion

In this section we discuss the possible sources of the selected recessions and the subsequent recoveries in South Australia in more detail. Results in previous section indicate that although none of the wedges could be safely ignored, the efficiency wedge is of first importance in explaining the economic fluctuations. Figure 4.12 shows the development of output and the efficiency wedge[5] from 1990 to 2014. It is interesting to explore why the efficiency wedge deteriorated during the recession episodes and what policies are

[5] In this section, data are nomalized to equal 100 in 1998.

Figure 4.11: Labour, Investment and Consumption Decomposition 2008-2014

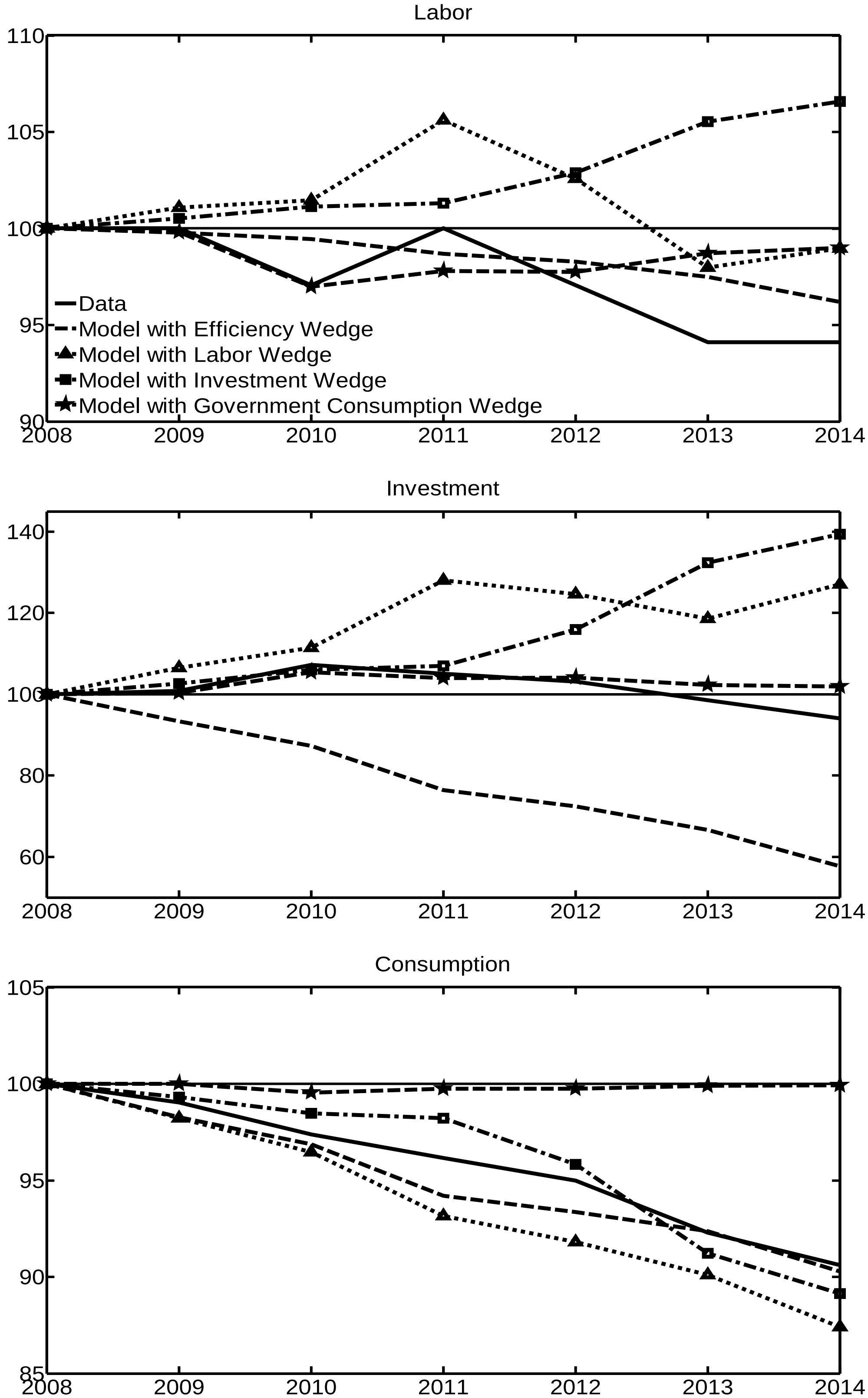
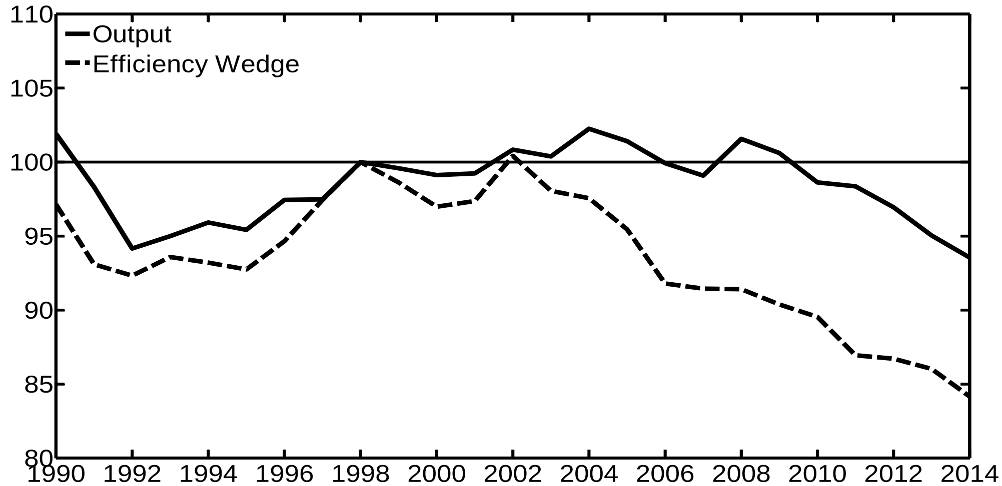


Figure 4.12: Output and the Efficiency Wedge



likely to attribute to the recoveries of the SA economy.

4.4.1 Understanding the Efficiency Wedge

There are several possible explanations of the efficiency wedge. For instance, frictions created by resource misallocation impact the Solow residual and therefore are captured by the efficiency wedge (Hsieh & Klenow 2007). Moreover, Burnside, Eichenbaum and Rebelo (1995) argue that cyclical movement in capital utilization is an important determinant of movement in the total factor productivity. Structural change was the main feature of SA's industry during late 20th century and early 2000s. The services industries that are more capital-intensive play an increasing role in SA's industry structure (O'Neil et al. 2004). Such structural change shifts resources (capital tends to flow from the traditional industries such as manufacturing into a more attractive industries) across economic sectors which may result in production deviations (Hancock & Hsieh 2006). Moreover, the motor vehicle industry in SA has been challenged by the continuously falling prices over the past decade. This may be attributed to competition from imports, overcapacity in global motor vehicle production, and reduction in tariffs (Halim et al. 2013). Consequently, pressures to reduce costs caused large amounts of human capital to be idled or misallocated , which might account for the decline in the efficiency wedge since early 2000s.

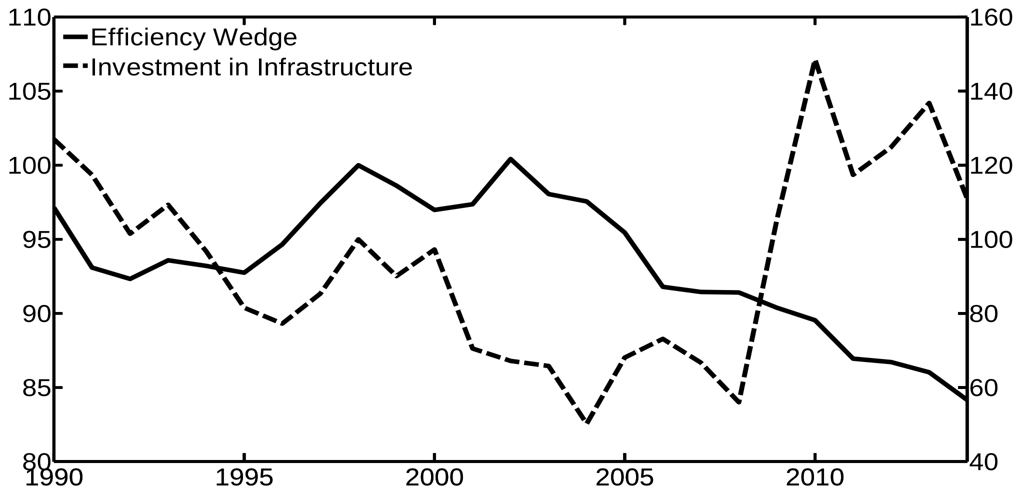
Hansen and Prescott (1993) show that changes in government regulations may also interpret the production deviation. In particular, public expenditures in health, education and infrastructure provision is prominent for the total factor productivity of the economy (Aschauer 1989).

> "There is also the role of State Government as a producer to consider. State and local governments in South Australia account for around 15 percent of final demand. The effectiveness of these expenditures, for instance in health, education and infrastructure provision, has a significant impact on the productivity of the economy. Indeed, these may be the areas in which State Government has most influence on productivity." (Hancock & Hsieh 2006, p.19)

To test this hypothesis, we use the value of work done by public sectors on engineering construction activity in SA as the measure of infrastructure investment. This data set includes the value of work done for the public sector in roads, bridges, electricity generation, water storage and supply, telecommunications and heavy industries etc. These are all relevant to South Australian core infrastructures. The series is detrended by its long-term average growth rates.

Figure 4.13 compares the efficiency wedge and investment in infrastructure over our sample period. The deterioration of the efficiency wedge in the early 1990s and during the Asian Financial Crisis could be largely attributed to the decline of the infrastructure

Figure 4.13: The Efficiency Wedge and Investment in Infrastructure

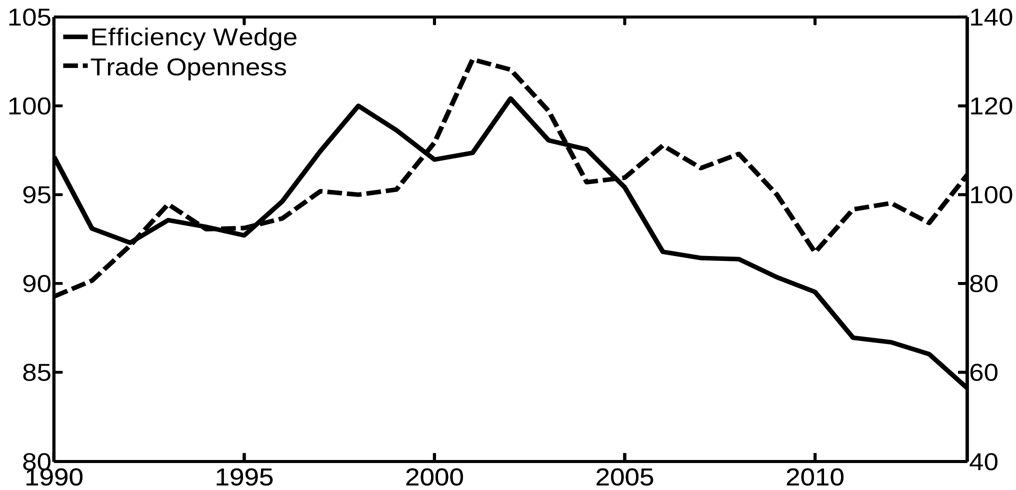


investment. For instance, the collapse of the State Bank of South Australia in 1991 forced the Bannon Labor Government to launch a bailout, which tightened the belt of the State government budget, forcing cuts in infrastructure investment in the early 1990s. Such spending cut might have adversely affected production process. Otherwise the construction of core infrastructures such as road and bridges would have helped firms to get rid of complicated paths, detour and circuity and therefore reduce their time consumed and increase productivity.

It is worth noting that the investment in infrastructure soars in 2008. This coincides with the government's stimulus packages. Rudd government has taken actions including backing all bank deposits and a $10.4 stimulus package (Local Government Association of South Australia 2008). The state government also engaged in the alignment of development policies and stimulus measures at the onset of the GFC. Such stimulatory fiscal policy should have prevented SA from recession during the GFC, there must be other factor that reduces the efficiency wedge.

After the GFC governments withdraw the implemented stimulus, which brings SA into

Figure 4.14: The Efficiency Wedge and Trade Openness



another recession. It is argued that the withdrawal has appeared too early (Halim et al. 2013). Australia has undergone a structural transformation, which has led to declines in the role of manufacturing sectors and increases in the importance of the service industries. However, the South Australian economy still has a higher dependence on manufacturing and agriculture industries due to its factor endowments, reflecting its weakness in business investment. The recent government's investment in major infrastructure projects including the Northern Expressway and South Road Superway are likely to reduce the production inefficiency.

Another explanation claims that trade openness would affect the efficiency wedge (Alcala & Ciccone 2001, Bolaky & Freund 2004). An economy can benefit from trade as it helps increasing competition, transfering knowledge and specialisation (Shanks & Zheng 2006). This would in turn shift the economy's aggregate production technology and the efficiency wedge. To evaluate this hypothesis, we use the ratio of the sum of imports and exports of goods and services over output in SA as the measure of index of trade openness. Figure 4.14 depicts the comparison results.

Figure 4.14 shows that trade openness and the efficiency wedge do not follow the same pattern during most of the time from 1990 to 2014. However, it might be an important contributor that brings the South Australian economy out of the Asian Financial Crisis. Notably export in SA saw a boost between 1999 and 2002 due to increases in exports of wine and motor vehicles (O'Neil et al. 2004). Moreover, the decline of the efficiency wedge in 2008 might also be attributed to trade openness. South Australian export performance was subdued during this recession. One possible culprit is the sharp decline in sales of locally produced motor vehicles.

The SA Government Economic Statement (2013) indicates that one of the important stimulatory pillars is the public infrastructure, which is proposed to stimulate the demand and production in the economy. Trade openness is also a productivity engine.

4.4.2 Productivity Growth: Comparison with Other States

There are a wide range of factors that could foster productivity (or increase the efficiency wedge) and output. Dawkins and Rogers (1998) divide them into two categories: factors affecting productivity 'level' and factors affecting productivity 'growth'. For example, they argue that scale and scope of firm, capital intensity could be determinants of productivity level. It is well known that SA is lacking large-scaled companies and has very few corporate head offices. Moreover, although capital intensive industries are now becoming more important, agriculture and manufacturing sectors are still playing a larger role in SA's industry structure compared with other states of Australia (O'Neil et al. 2004). These may partly explain the subdued South Australian economic behaviour in comparison with the rest of Australia.

In subsection 4.4.1, we stress the importance of public infrastructure and international openness to the South Australian economy (productivity). These are classified by Dawkins and Rogers (1998) as factors affecting both level and growth of productivity and subsequently affecting the growth of output. It is interesting to observe how these 'productivity growth engines' look like in other states of Australia. As a comparison, Figures 4.15 and 4.16 show the investment in infrastructure to output ratio and trade openness index of major states[6] and Australia (AUS). Figure 4.17 depicts their GSP per capita.

It is clear that in both terms SA is weaker than most of the other states in Australia, which is in line with the fact that South Australian economic growth has lagged behind the rest of Australia. However, since 2009 the public infrastructure investment to output ratio in SA is second only to QLD and surpasses it in 2013, which may be due to the robustness of expenditures on roads, highways and subdivisions in some degree (Halim et al. 2013). It is notable that QLD has the largest infrastructure to output ratio throughout the period 1990-2013. QLD has the advantage of a large tourism industry, meaning substantial visitor arrivals, tourist spending and investment in infrastructures. As to international openness, SA's index is lower than other states and far behind WA. The economy of WA is closely linked with natural resources industry and therefore contributes more than half of Australia's mineral and energy exports. As a result, GSP per capita in QLD and WA outperform all other states and well above SA and the national level, as indicated in Figure 4.17. The crucial role of public infrastructure and trade openness on economic growth (productivity growth) is apparent.

[6]Including SA, Queensland (QLD), Victoria (VIC), New South Wales (NSW) and Western Australia (WA).

Figure 4.15: State Investment in Infrastructure to Output Ratio

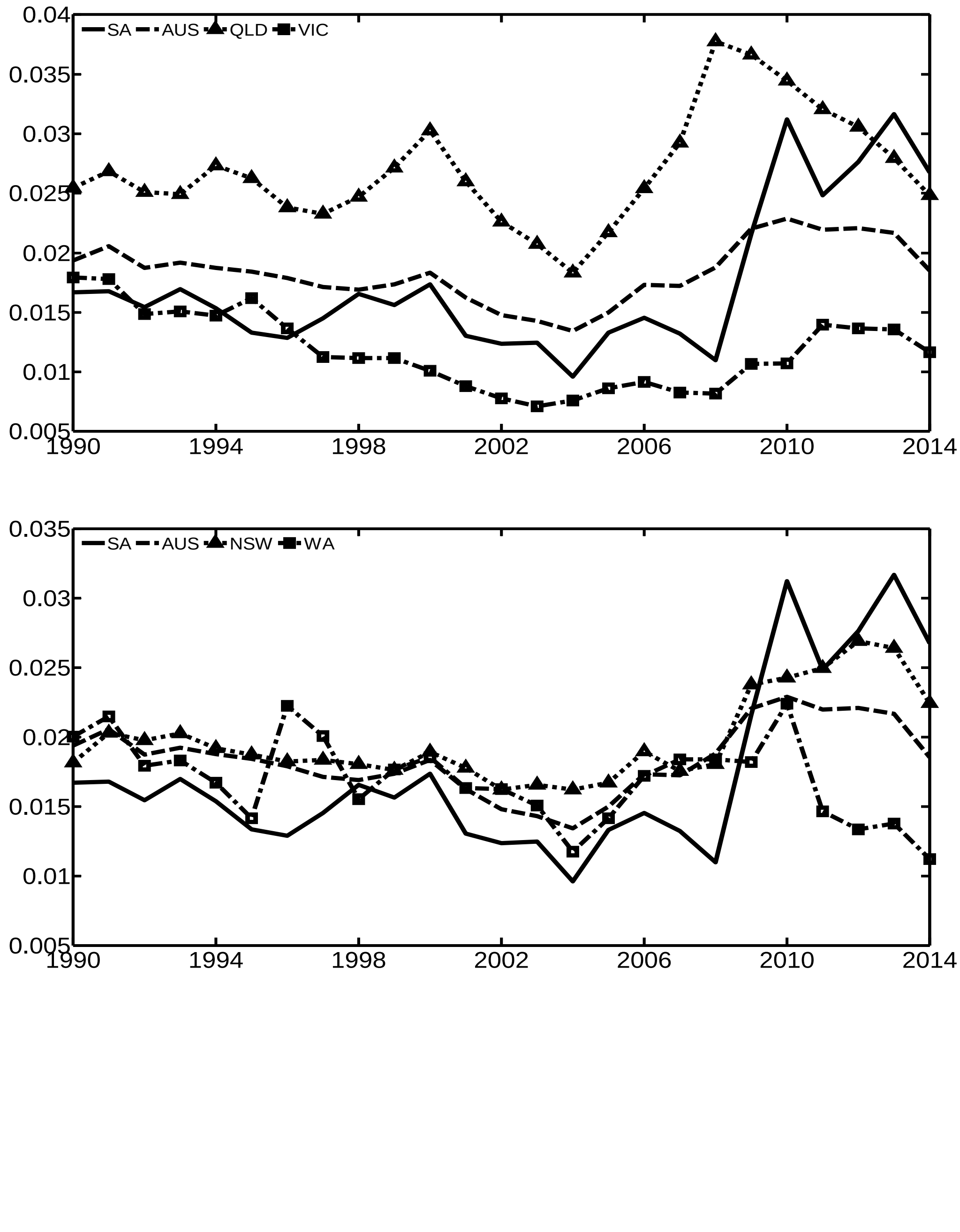
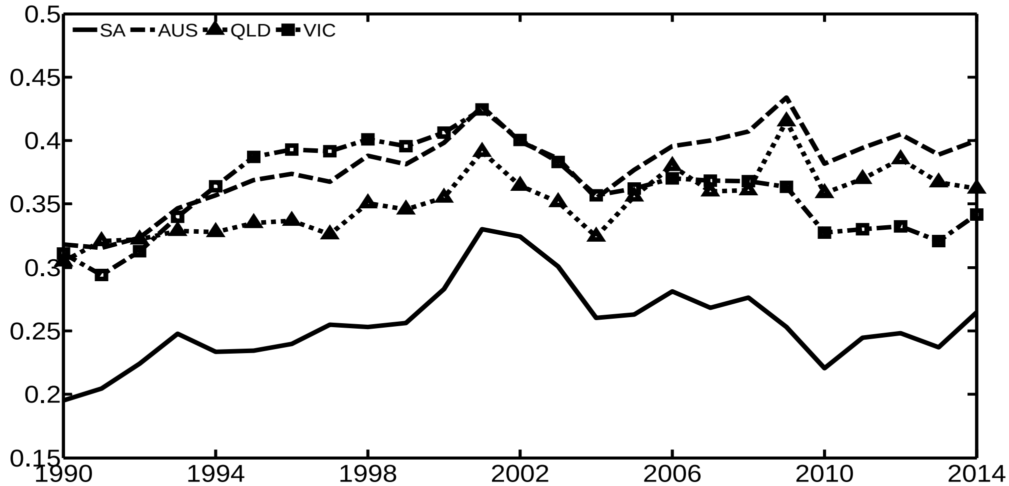


Figure 4.16: State Trade Openness



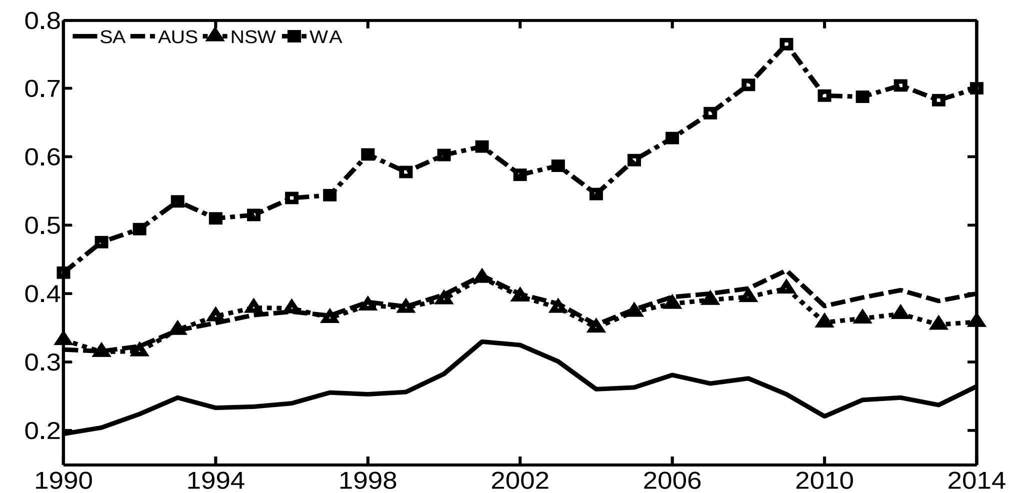
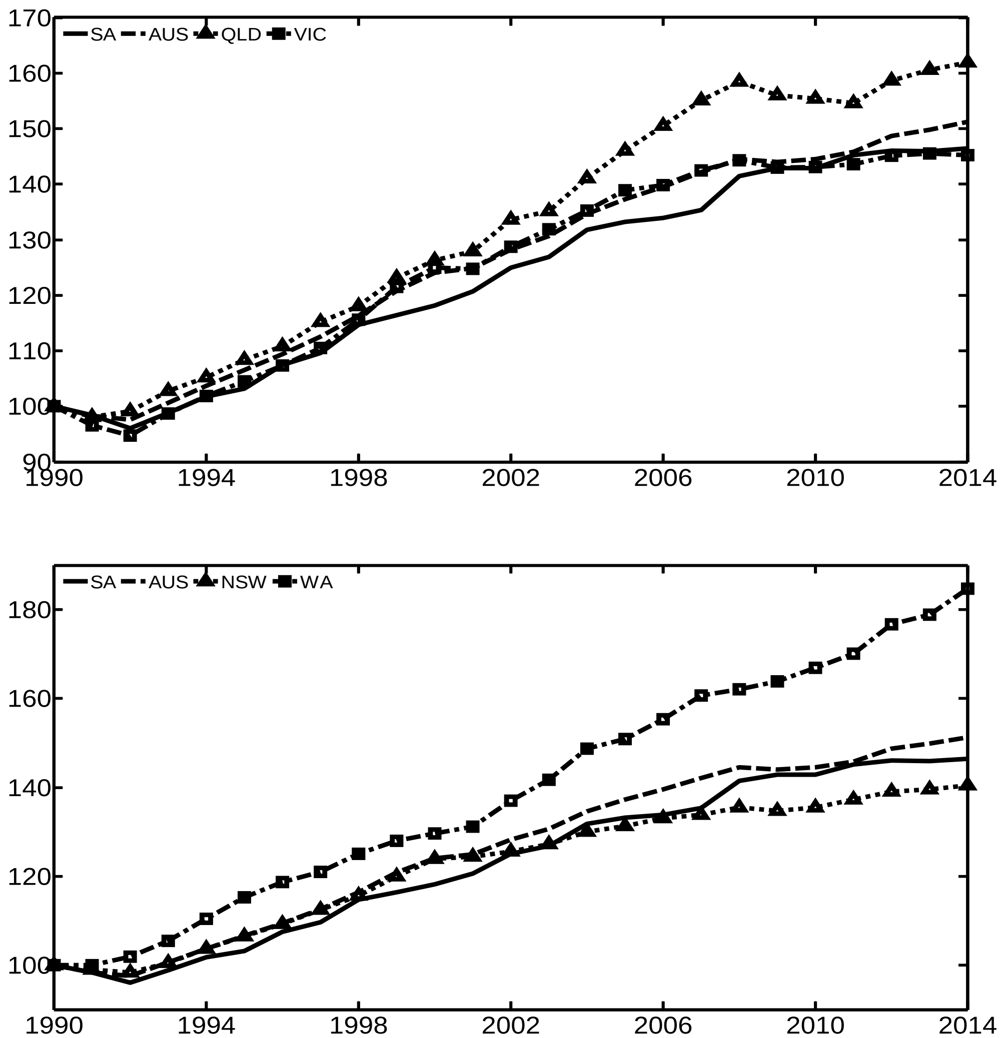


Figure 4.17: Index of Real GSP (1990=100)



4.5 Conclusion

We apply Chari, Kehoe and McGrattan (2007) accounting method to decompose the fluctuations of the South Australian economy from 1990 to 2014 into its sources. We focus on three major downturns: the recession in the early-1990s, the Asian Financial Crisis and the most recent recession. Our results show that the efficiency wedge is the primary transmission channel through which the external shocks hit the South Australian economy. To better understand the behaviour of the efficiency wedge, it is necessary to explore the primary sources of the shocks. We show a few possible candidates of such shocks: structural transformation, the collapse of motor vehicle industry, decline in infrastructure investment and reduction of international openness. Notably, it is emphasized that investment in public expenditure and trade openness have significant impacts on the South Australian economic growth.

Appendix 4.A Trends and Business Cycles: South Australia vs. Australia

Figure 4.18: Trends and Business Cycles

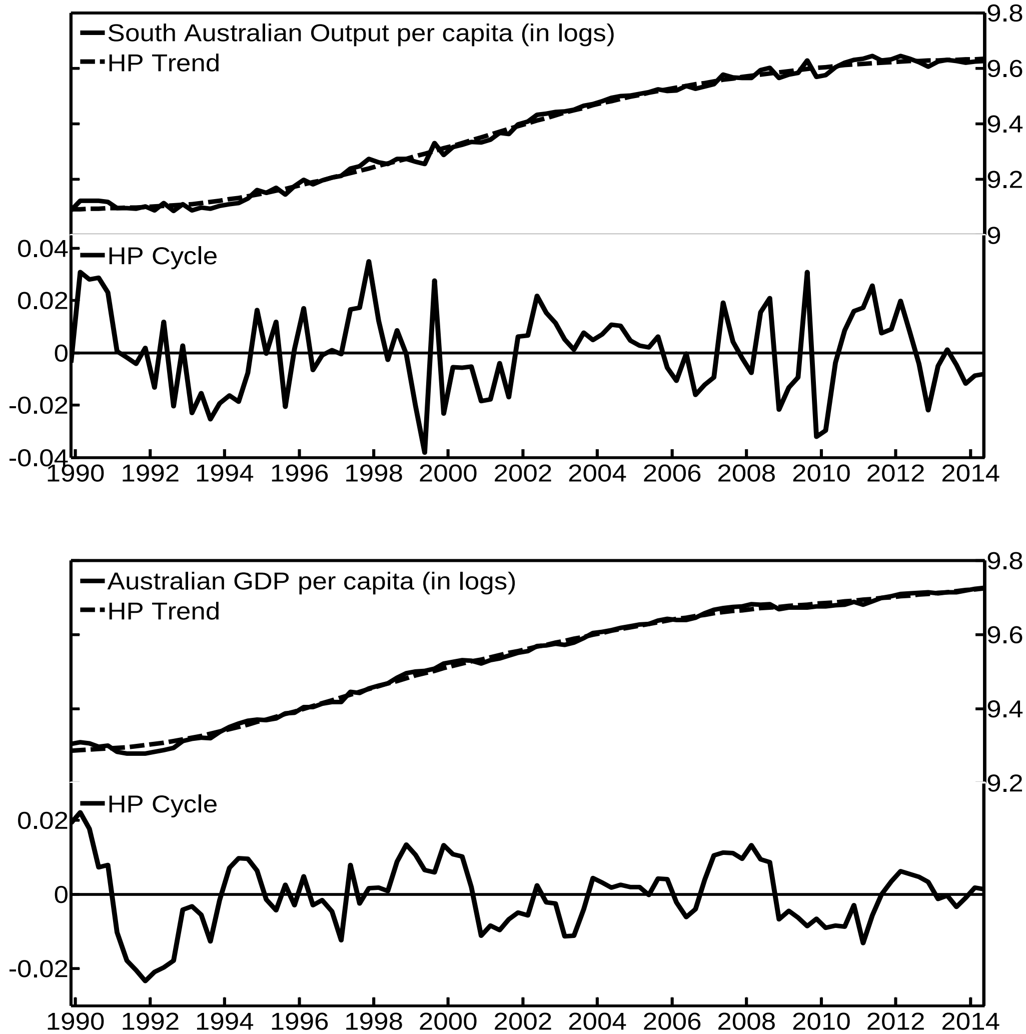


Figure 4.18 displays trends and business cycles (Hodrick-Prescott filtered) of South Australian aggregate demand, denoted as output in the graph, and Australian GDP. The most reliable measure of the economic activity is GSP which is unfortunately only available on an annual basis. However, state final demand (SFD) is published on a

quarterly basis. SFD excludes international and interstate trade as well as changes in inventories which are important components of the economy activity. Therefore we use the sum of SFD and net exports as a measure of aggregate demand that is close to GSP. The trend lines expose the fact that the South Australian economy grows slower than the rest of Australia, particularly after 2008.

Appendix 4.B Data Source

This Appendix provides the details of source and construction of the data used in this paper. The original source of the data is Australian Bureau of Statistics. Quarterly and monthly data are annualized unless otherwise stated in the paper. Data covers from 1990 to 2013.

4.B.1 Original Data

O.1. Resident Population, South Australia and Australia. Source: ABS Catalogue No. 3105, Table 1.5.

O.2. Gross State (Domestic) Product, Chain Volume Measures. Million Dollars. Source: ABS Catalogue No. 5220, Table 1.

O.3. Households Final Consumption Expenditure, Chain Volume Measures. Million Dollars. Source: ABS Catalogue No.5220, Table 5.

O.4. Households Final Consumption Expenditure on Furnishings and Household Equipment, Chain Volume Measures. Million Dollars. Source: ABS Catalogue No. 5220, Table 5.

O.5. Aggregate Monthly Hours Worked. Monthly, Seasonally Adjusted. Source: ABS Catalogue No.6202, Table 20.

O.6. Private and Public Gross Fixed Capital Formation, Chain Volume Measures. Million Dollars. Source: ABS No.5220, Table 5.

O.7. Total Compensation of Employees, Current Prices. Million Dollars. Source: ABS Catalogue No.5220, Table 15

O.8. Total Factor Income, Current Prices. Million Dollars. Source: ABS Catalogue No. 5220, Table 5.

O.9. Gross Mixed Income ,Current Prices. Million Dollars. Source: ABS Catalogue No. 5220, Table 15.

O.10. Taxes on the Provision of Goods and Services. Million Dollars. Source: ABS Catalogue No. 5506, Table 0do001 etc.

O.11. Gross State Product, Current Prices. Million Dollars. Source: ABS Catalogue No. 5220, Table 1.

O.12. State Final Demand, Chain Volume Measures. Quarterly, Seasonally Adjusted. Source: ABS Catalogue No. 5206, Table 29.

O.13. Resident Population, South Australia and Australia. Quarterly. Source: ABS Catalogue No. 3101, Table 4.

O.14. Value of Work Done for the Public Sector. Thousand Dollars. Source: ABS Catalogue No. 8762, Table 22.

O.15. Exports of Goods and Services, Flow. Monthly. Million Dollars. Source: ABS Catalogue No. 5220.

O.16. Imports of Goods and Services, Flow. Monthly. Million Dollars. Source: ABS Catalogue No. 5220.

O.17. CPI Index, All Groups, Adelaide. Quarterly. Source: ABS Catalogue No. 6401, Table 1.

O.18. Gross Domestic Product, Chain Volume Measures. Quarterly. Million Dollars. Source: ABS Catalogue No. 5206, Table 1.

4.B.2 Constructed Data

C.1. Real Per Capita Output=O.2./O.1.

C.2. Real Per Capita Consumption=(O.3.-O.4.)/O.1.

C.3. Real Per Capita Investment=(O.6.+O.4.)/O.1.

C.4. Per Capita Hours=O.5./O.1.

C.5. labour Share (Measure 1)=O.7./(O.11.-O.9.-O.10.)

C.6. labour Share (Measure 2)=O.7./O.8.

C.7. Aggregate Demand=O.12.- (O.15.-O.16.)

C.8. Real Investment in Infrastructure=O.14./O.17.

C.9. Trade Openness Index=(O.15+O.16)/O.11.

C.10. Quarterly Real Per Capita Output=C.7./O.13.

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