Productivity-wage-growth nexus: an empirical study of Singapore

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1 November 2011

Productivity-Wage-Growth Nexus: An Empirical Study of Singapore

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2011

Abstract

This paper investigates the empirical relationship between labor productivity, real wages and real GDP in Singapore from 1997 to 2011. The paper begins with a review of productivity, wage and growth situations in Singapore in the past decade and further attempts to uncover the underlying relationship in this nexus using theoretical framework from labor and growth literature. Using the Vector-Autoregressive or Vector-Error Correction Mechanism when cointegration is present, this paper uncovers various causality relations in different industries which conform to economic theory and empirics. An impulse response analysis is also undertaken to understand how specific policy decisions could be framed to provide for higher wages across industries. The empirical results suggest that in the Singapore economy, there exist a bi-directional causality relation between labor productivity and real GDP but that wages seem to be caused by other underlying factors. However, real wages respond positively to positive shocks in the real GDP or labor productivity using cholesky or generalized decomposition. This paper concludes by discussing policies that could be undertaken to promote inclusive growth in the environment of sustained economic growth.

JEL Classification Codes: C22, J30, O40

Keywords: Causality, Productivity, Wage, Economic Growth, Singapore

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1.0 Introduction

The understanding of real gross domestic product (RGDP), labor productivity (LP) and real wages (RW) have come a long way since demand and supply mechanisms. Jorgenson (1991) influential paper have helped economist understand how labor, capital and total factor productivity had driven economic growth in both theoretical and empirical framework. Mortensen and Pissarides (1999) efforts in labor search and match have also helped to pave theories on how wages and employment are bargained and set.[1]

However, there still exist many uncertainties when productivity, wage and growth (PWG) are considered together. Does increment in productivity cause wages to increase? Will an exogenous wage increase help boost real GDP? Does a fall in GDP induce falling productivity? These are the uncertainties this paper tries to answer in the context of Singapore since each hypothesis leads to different policy implications.

As mentioned by former Minister Mentor of Singapore, Mr Lee Kuan Yew, in his 2010 speech to Singaporeans, "If we cannot increase the productivity or the output of our citizens, our economy will slow down. We will have a deflating economy, with a series of knock on effects as prices of all assets, including flats will go down... demand will lessen, pay will fall and so will the number of jobs and promotions." In this case, his beliefs are that increasing productivity causes GDP growth which in turn causes wages to rise. However, there are serious omissions in the feedback channels for which this paper will now explain.

This paper aims to understand the dynamics of PWG relation in Singapore. There is minimal empirical work carried out in this area in Singapore, most notably due to the

[1] In fact, both influential papers assumes different conditions on workers and markets in their explanation of the steady state path of economic growth, productivity and wage bargaining and have not been reconciled.

availability of data. This paper aims to contribute by, firstly, studying how each industry has performed in terms of PWG so as to assess the changing economic conditions in Singapore, secondly, using econometric methods, understand the PWG nexus relationship via granger causality and lastly, understand whether real GDP or labor productivity is more effective in driving changes in real wages.

To begin, an in-depth analysis of PWG environment in Singapore is examined. The National Wage Council (NWC) helps guide wages while productivity and labor productivity is campaigned by SPRING Singapore and Ministry of Manpower (MOM). The Singapore government recently concluded their Economic Strategies Committee (ESC) report with the idea of "sustained and inclusive growth". This paper takes precedence with this in mind.

Although statistical in nature, the PWG nexus supports important theories. Hall and Lilien (1980) advanced the efficient wage hypothesis where higher wages induce higher productivity while Haltiwanger and Lane et al. (2007) commented that higher productivity give rise to higher pay which is better known as performance-based bargaining. Kaldor (1959) in his seminar work showed how higher growth rates could feed into higher wages which channels back into growth. Fields and Wan (1989) using empirical analysis discussed on how Singapore fell into a recession after rapid wage increments in previous years due to loss of export competitiveness. However, Barros (1993) showed otherwise, meaning higher wages drive GDP growth. Next, for relation between labor productivity and economic growth, Atesoglu and Smithin (2006) empirical work on G7 nations from 1960 – 2002 proved a direct relationship using the theoretical framework of Kumar and Russell (2002).

The analysis of the literature and data leads to a few conclusions in Singapore. First, in general, real GDP growth has outperformed growth in real wages which has risen faster than labor productivity from 1997 to 2011. This means that wage share has risen while profit

share has fallen which supports finding of low productivity growth yet high economic growth in Singapore[2]. Further, the financial service (FS) sector registered the highest increment in real wages followed by the manufacturing (MANU) sector even when labor productivity was flat in the former while productivity growth was greatest in the latter. The hotel and restaurant (HR) industry had falling productivity and real wages supporting the notion of lowly-skilled foreign labor entry in the mid 2000s.

Second, econometric methods employed in VAR or VEC techniques conclude that in general, wages in Singapore are not granger caused by real GDP growth or labor productivity growth. However, a more detailed analysis showed that the government's call for re-training of manufacturing workers could help boost the sector's GDP and real wages. In the construction (CON) sector, it seems that efficiency wage theory works best as wages does seem to granger cause labor productivity.

Lastly, impulse response analysis made using cholesky or generalised impulses reports similar results that in general, a positive exogenous shock in labor productivity would help increase real wages greater than increment in real GDP. The relation however does not hold in the wholesale and retail sector sector where real wages fell with increasing productivity instead in the long run. The analysis would help us understand how to generate greater incomes for workers in order to bring about inclusive growth.

The rest of the paper is organised as follows: the next section describes about literature pertaining to Singapore and global PWG theory and empirics. Section 3 explains the econometric methodology used in the analysis while Section 4 presents the empirical findings with reference to Singapore. Section 5 concludes.

[2] Paul Krugman's comments on Singapore productivity and economic growth.

2.0 Literature Review

This section first discuss about the Singapore economy and its pursuit of economic growth, raising productivity and higher wages. Next, the definition of PWG in this context is clearly explained before theoretical frameworks between them are discussed.

2.1 The Singapore Economy

The Singapore economy is a one that has achieved tremendous success in economic growth. In the past decade, real GDP rose 5% per annum. This was due to strong performance in the diversified economy. Real median income however only rose 20% for the decade while labor productivity 1% per annum mainly due to poor performance in the hotel and restaurant and construction industry.[3] This motivated a strong drive by the government to encourage her citizens to innovate and grow through raising productivity. The NWC also proposed employer to raise real income only when productivity has risen.[4]

The Singapore economic landscape has also shifted. Manufacturing has taken a larger share of GDP from 22.6% to 27.7% in between 1997 and 2006. This was mirrored by a fall in construction from 7.9% to 3.6% and a relatively stable service sector.[5] The changes in economic landscape are also mirrored in productivity where construction's labor productivity began to fell in 1995. In this case, manufacturing labor productivity increased at higher rates of 3% to 8% per annum while service sector grew at a lower rate of 1% to 6%.[6] This is also mirrored in average wage changes where construction had 1.4% increment in wages per annum compared to 5%-6% growth in wages in manufacturing and service sector according

[3] Economic Strategy Committee Paper.

[4] NWC guideline 2011/2012.

[5] Singstats yearly paper2007 according to SSIC 2005.

[6] MTI Singapore productivity performance report.

to Wong and Heng (2001). But, approaches in different papers were incoherent. To begin, aggregated Consumer Price Index (CPI) is used as deflator leading to measurement error. Further, labor productivity is also poorly defined. Thus, this paper aims to clarify these issues and provide a coherent viewpoint in the following segments.

2.2 Labor Productivity, Real Wages and Real GDP Growth

Labour productivity is defined in general as output per unit labour or hours worked depending. Solow (1956) and many influential growth models use the former. In this case, changes in labor productivity is often used in wage bargaining which helps derive competitiveness and thus growth in a country. It reflects the joint efforts of technology, capital investment, quality of workforce and efficient management practices.

Next, nominal quarterly earnings refers to all remunerations received including basic wage, overtime pay, work allowances and all kinds of bonuses. In Singapore's case, it does not include CPF contribution by employer. Changes in earnings could be due to changes in overtime and composition of workforce. It is crucial to note that real wage is preferably adjusted for inflation using GDP deflator as put forth by Feldstein (2008) and Mankiw[7] as adjustment using CPI would not be fair in accessing how real income changes in relation to changes in real GDP. This is because every industry has its own GDP deflator to recognise both the price and compositional changes while CPI only measures the changes in prices in goods and services consumed. Further, CPI is not relevant to the national income accounting of real GDP and real wages. Hence, in this case, real GDP and real wages would best be adjusted by specific industrial deflator which is practiced in this paper. With these understanding, this paper can now dwell on theoretical frameworks supporting the PWG.

[7] Gregory Mankiw's comments on wages and productivity on his blog.

First, there is a strong relationship between real wages and labor productivity. Wakeford (2004) showed that a cointegrating relationship between productivity and wages in Africa based on specification by Blanchard and Katz (1999):

$$\ln w_t - \ln p_t^e = \alpha + \beta \ln prod_t + \omega(\ln w_{t-1} - \ln p_{t-1}) + \phi u_t + e_t \quad (1)$$

where w, p, prod and u represents wages, prices, productivity and unemployment respectively. Narayan and Smyth (2009) also found similar empirical relevance in the G7 nations. In this case, the MRP theory postulate that employers practice performance-base wages and recruit up to point where marginal product of labor equals the marginal cost which is real wages thus inducing workers to work harder for higher pay. Another viewpoint would be the efficiency wage theory where Akerlof and Yellen (1990) suggest that workers would not employ as much efforts or shirk if they are paid below the fair wage. Therefore, on macro-levels, higher wages would induce higher productivity as cost of job loss is greater.

Second, there seems to be an association between real GDP and real wages. The issue in discussion is whether the former induces the latter or otherwise. Fields and Wan (1989) argued that it was the sudden wage increase from 1979 to 1982 that had eroded competitiveness in the Singapore economy leading to slow growth and recession years later. However, Erixon (1997) showed the an autonomous wage increment led to the restructuring of Sweden's economy which led to high real GDP growth known as the golden age. Barros (1993) extended the Lucas endogenous growth model by making employment rate endogenous and dependent on productivity leading to a simplified expression:

$$y = \beta^{\delta} H^{\frac{b+a}{a}} (uL) \quad (2)$$

where y represents output while the (HuL) represents derived labour inputs assumed as real wages and parameters are assumed positive.[8] The paper goes on to show empirically the Brazilian economy having higher GDP due to higher wages and restructuring. The issue of growth leading to higher wages is even of higher complexity as it depends greatly on institutional and employee bargaining. Thus, volumes of literature have been inconclusive at best.

Third, labor productivity is deemed to have a strong relationship with economic growth. In OECD nations, it is found that roughly half of growth in real GDP per capita is due to labor while the other is due to labor force participation rates and immigration policy. Atesoglu and Smithin (2006) also proposed and applied their theoretical model[9] to G7 nations from 1960 - 2002. They concluded that labor productivity had a positive relation with real GDP for all countries while it has only positive relationship with real wages for some. Higher real GDP would also stimulate growth in fixes investment leading to higher productivity as commented by Chow (1968) and Phillips (1954). This is better known as the accelerator-multiplier principal.

This paper thus considers endogenising all three macroeconomic variables as there lies strong relations to be uncovered. By doing so, this paper hopes to understand relationships between leads and lags of the variables and overcome simultaneity issues by allowing for feedback in the system. The VAR-VEC mechanism is thus considered in the following.

[8] More details and derivations of the extension of Lucas model in Appendix A.

[9] More details on the six equations in the endogenous Atesoglu-Smithin model found in journal paper.

3.0 Data and Methodology

This section explains the techniques used to handle the data and econometric methods including unit root tests, cointegration tests and VAR or VECM applied in the PWG nexus.

3.1 Data Set-up

This paper uses quarterly data obtained from MOM and Singstats from 1997 to 2011. The main datasets include nominal GDP, labor productivity index, nominal wages and GDP deflator index. These are all collected in individual industries and economy as a whole. The nominal GDP and nominal wages are adjusted for inflation using GDP deflator. Due to changes of SSIC from 2000 to 2005 in the nominal wages, business service is defined as the sum of real estate activities, professional activities and administrative and support activities similar to definitions in the SSIC report. Storage, transport and information-communications are also adjusted into one component by taking averages for PWG. In the case of aggregation and averaging, weights are found to be significant by Ordinary Least Squares and are checked with periods of overlap. The difference, if any, is less than one standard deviation. Eight groups of PWG nexus are formed. All variables are transformed into natural logarithms and seasonal adjustment is made using quarterly X12-multiplicative process if required.

3.2 Specification and Estimation

In order to proceed, real wages, labor productivity and real GDP are tested for stationarity. This is important as non-stationary regressions could lead to spurious results. The Augmented Dickey-Fuller (ADF) was chosen because of its high powers and tests were conducted in levels and first differences and results are based on the significance of the t-ratio. The lag lengths for the ADF test were selected to achieve white noise residuals.

Since variables are found to be nonstationary, the next step is to estimate the VAR or VECM correctly. First, a maximum lag length of 6 is chosen in a VAR to estimate the PWG nexus. The correct lag length is chosen by a series of sequential test where the lowest Akaike information criterion (AIC) was chosen. Although the SIC criterion is consistent, this paper uses the AIC as models chosen by SIC criterion fails many other diagnostics. Further, SIC chooses first lags in most instances and according to Toda and Yamamoto (1995), more lags could be added which in fact gives the lag choice of AIC criterion.

Once the correct lag length is chosen, the next Johansen procedure is applied to test for cointegration amongst variables. In brief, the Johansen procedure is used to estimate the coefficient matrix from an unrestricted VAR and to test one can reject the restriction placed on the coefficient matrix which in this paper is chosen to be whether the level data has linear trends while the cointegrating equations have intercepts. The results are analysed using the maximum eigenvalue test and trace test. Should a cointegrating relation be found, a VECM can be estimated to account for short term error corrections in the long term equilibrium.

To ensure that cointegration test is robust, this paper also employs the Gregory Hansen cointegration test to test if the null of no cointegration could be rejected to ascertain alternative of cointegration with possible structural breaks. These results confirm the presence of cointegration in the Johansen procedure. From here, this paper performs model checking to ensure the model represents the DGP adequately. The serial correlation test is of utmost importance as it affects the statistical inferences of the estimated model and hence restrictions on VAR or VECM could be imposed wrongly. To overcome this issue, more lags are added and models are re-checked. Test for normality is also carried out as non-normality could indicate that model improvements are possible. Afterwhich, the best model is chosen.[10]

[10] The theoretical framework of the VAR and VECM estimation and tests are explained in Appendix B.

3.3 Granger Causality

Granger (1969) proposed a definition of causality in which variable x is causal for variable y if x is has helpful dynamic relations to y. This structure has since been extended to VAR and VECM frameworks with multiple variables and research is still on-going. This paper employs the following system framework:

$$\begin{aligned}
\Delta lp_t &= c_{1,t} + \sum_{n=1}^{k} \alpha_n \Delta lp_{t-1} + \sum_{n=1}^{k} \beta_n \Delta gdp_{t-1} + \sum_{n=1}^{k} \chi_n \Delta w_{t-1} + \phi_1 ECT_{t-1} + e_{1t} \\
\Delta gdp_t &= c_{2,t} + \sum_{n=1}^{k} \eta_n \Delta lp_{t-1} + \sum_{n=1}^{k} \varpi_n \Delta gdp_{t-1} + \sum_{n=1}^{k} \tau_n \Delta w_{t-1} + \phi_2 ECT_{t-1} + e_{2t} \\
\Delta w_t &= c_{3,t} + \sum_{n=1}^{k} \vartheta_n \Delta lp_{t-1} + \sum_{n=1}^{k} \lambda_n \Delta gdp_{t-1} + \sum_{n=1}^{k} \iota_n \Delta w_{t-1} + \phi_3 ECT_{t-1} + e_{3t}
\end{aligned} \tag{3}$$

where lp, gdp and w represents labor productivity, real GDP and real wages. In addition, ECT represents the error correction term, if applicable. The serially independent random errors are given by e and have zero means and finite covariance matrices. Due to the mix of VAR and VECM models estimated, this paper employs the Granger non-causality test by using Wald chi-square tests on the lagged variables.[11]

3.4 Impulse Response Functions

The impulse response function (IRF) is applied to account for innovations in the VAR or VECM model. The shock to the i-th variable in this case not only affects the i-th variable dynamically but is also transmitted to all other variables in the system. An accumulated impulse response function used in this paper thus traces the effect of a one-time shock to the innovations on current and future values of the endogenous variables. If innovations are contemporaneously uncorrelated, this system can be easily interpreted. However, if innovations are correlated, in order to separate the effects, transformation by means of cholesky decomposition and generalised impulse decomposition are applied and hence,

[11] Recent causality literature applies different methods to test for long-run causality and different approaches have given different results. Thus, this paper uses the most fundamental method used by Granger (1969).

VARs or VECMs need to be ordered in the former.[12] In fact, using the generalised method or by ordering wages first followed by real GDP and real productivity, both impulse response functions converge in results.

4.0 Empirical Results and Policy Recommendations

This section examines the relationship from a farcical basis before understanding about the PWG nexus in each industry and the economy as a whole. The impulse response of wages to changes in real GDP or real productivity is also examined to answer the question of whether a growing the economy or a growing the productivity helps wage increment more. Some policy decisions are discussed.

4.1 Preliminary Data Analysis

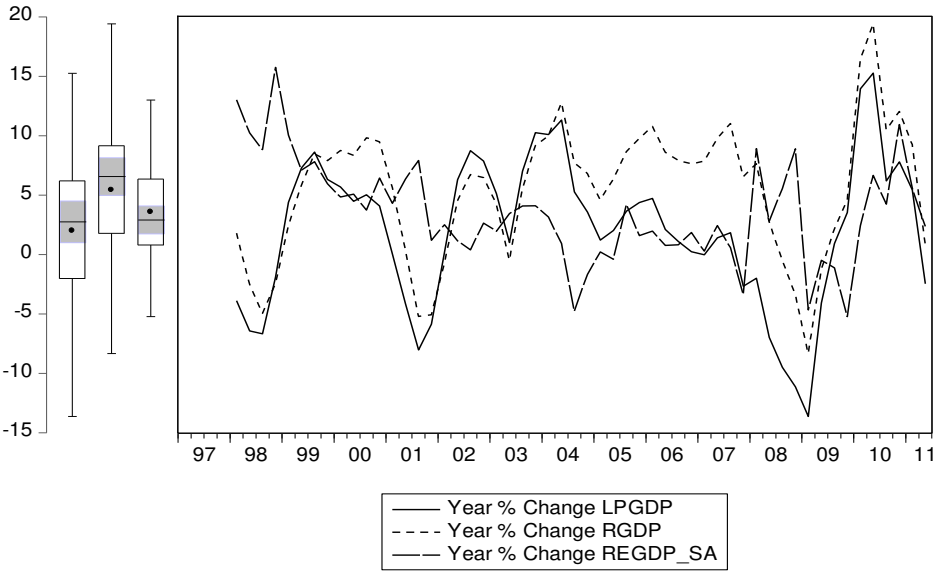


Figure 1.1 YOY change in PWG with Box-plot

As shown in Figure 1.1, labor productivity mimics real GDP fairly well from 1997 to 2003. However, divergence occurred by 2004. This is notably because of the relaxed immigration policy in which non-residential and permanent residents increased by 64% and 40% respectively from 2005 to 2010. This led to the influx of foreign workers, who along

[12] More discussion on can be found in Appendix C.

with low skill levels, have driven economic growth in Singapore but not productivity growth in general. Next, labor productivity in fact tracks real GDP fairly well through extreme periods of Asian Financial Crisis (AFC) in 1998, Dot-Com bubble in 2001 and Global Financial Crisis (GFC) in 2009. Real wages however seem to be countercyclical in general and in fact lags changes in real GDP by three to five quarters as seen from AFC, GFC and years of economic growth. Therefore, wage seems to take on the path chartered by NWC which is 'wage increases should lag behind productivity growth'.[13] Further, wages have also been much less volatile than real GDP and labor productivity in recent years perhaps due to the government's call for stable wages and reforms in the wage component to make do with a higher variable component pegged on economic growth. Thus, real wages are very much influenced by government actions.

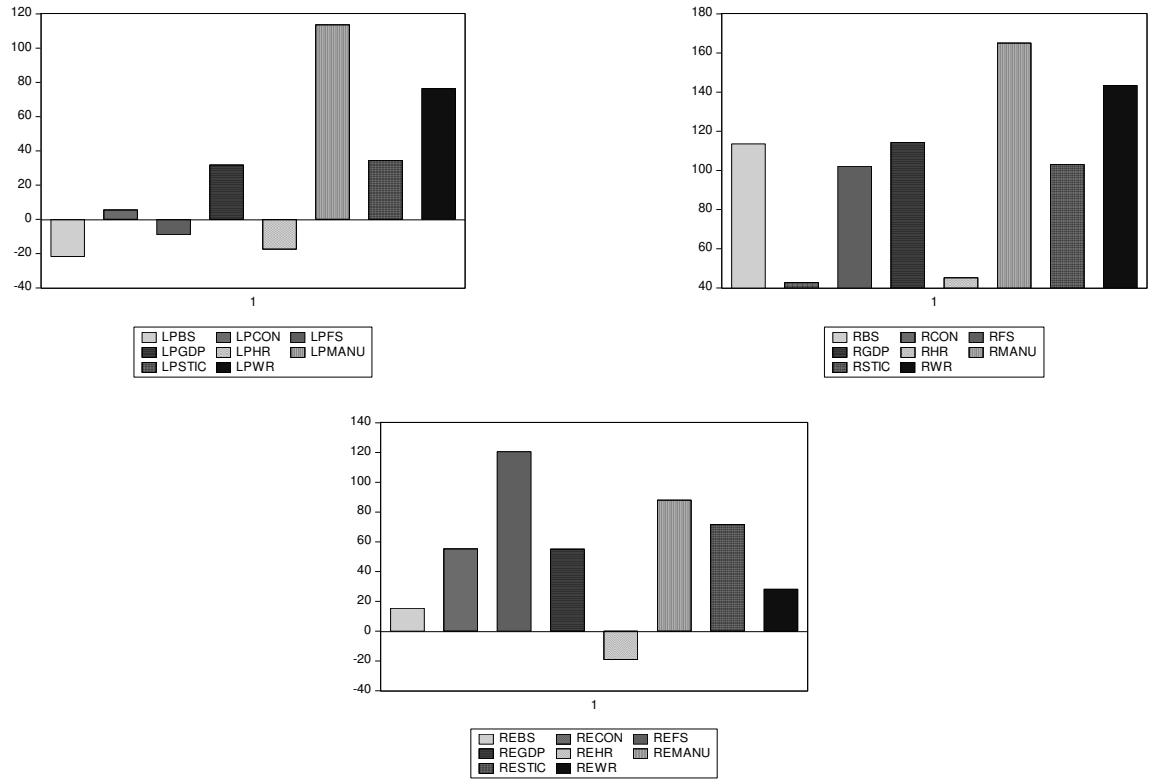
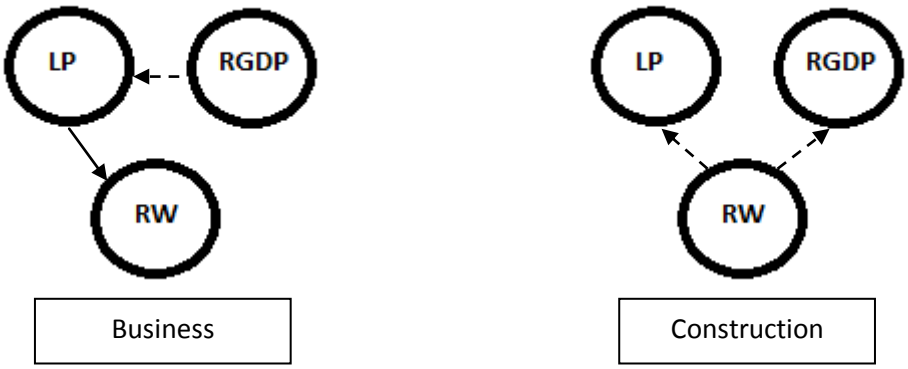


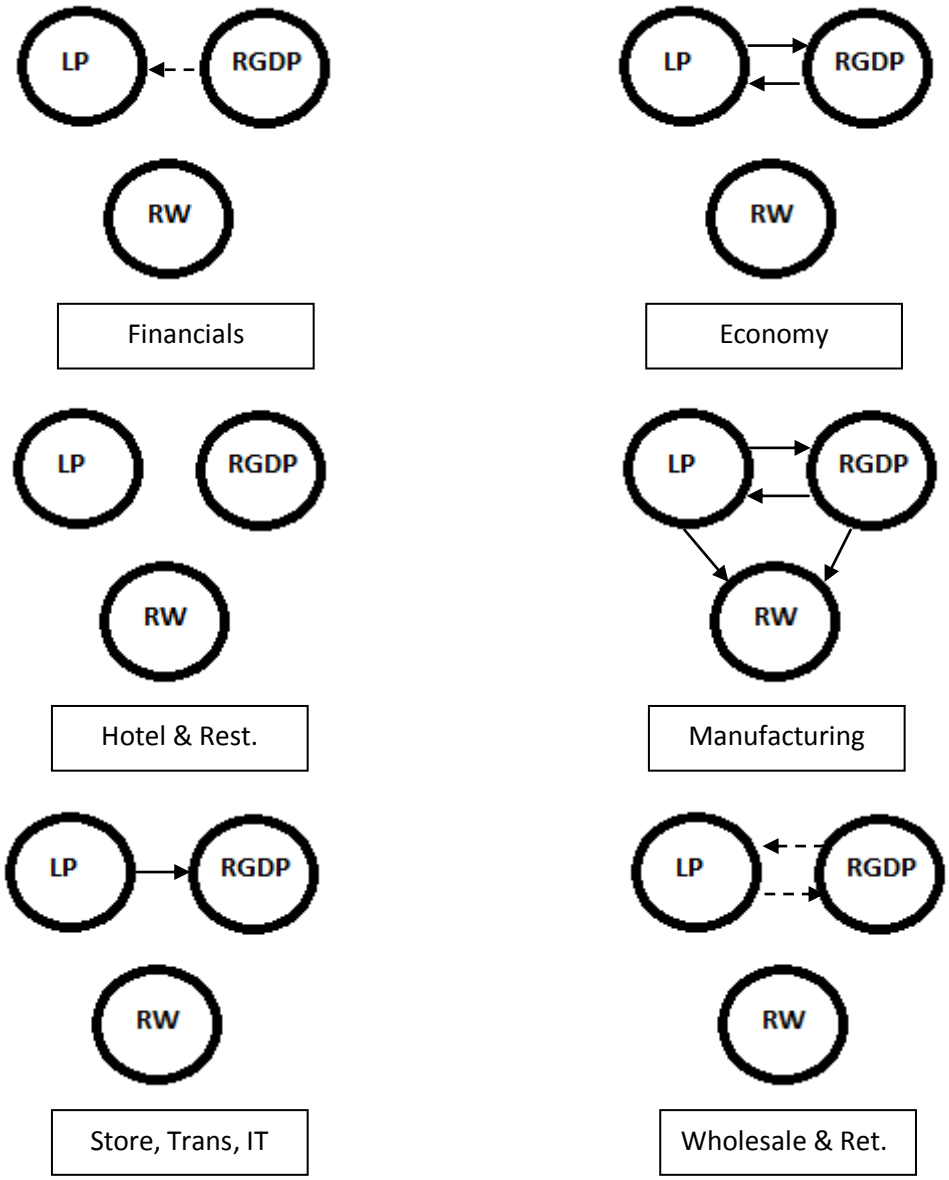
Figure 1.2 Percentage change for PWG from 1997 to 2011

[13] Mentioned in NWC circular Wage Reform and Tripartism: A test of trust at work.

A closer examination in Figure 1.2 leads to better understanding of each industry. As shown, wage growth in financial sector is the highest followed by manufacturing. However, productivity growth in financial service is negative compared to the strong productivity growth in manufacturing. In short, these findings show that government may need to do more to boost productivity in the manufacturing output service than financial service to bring about wage growth. Moreover, the hotel and restaurant sector, with low base wage, is having negative wage growth in the past decade in line with negative productivity growth. With further developments in tourism, it is important to encourage F&B employers to re-design job scope, train and pay local workers more before a mass exodus of workers to other sectors leading to a need to bring in more foreign labor which further lowers productivity. Due to the flat productivity and high increment in wages in construction and financials, there is eroding cost competitiveness. During economic growth, the issue is not obvious. However in economic recession, these sectors may turn volatile in terms of employment. Hence, NWC may need to help firms set and mange right hiring expectations. In general, wage share has risen and profit share has fallen in the economy which may hamper foreign direct investments into the future. This paper now turns to causality analysis to understand the casual linkages.

4.2 Productivity-Wage-Growth Nexus Relation





Note:- - → means significance at 5% while ⟶ means at 1% level

Figure 2.1 PWG Nexus of Industry and Economy

The PWG causality shown in Figure 2.1 depicts significance of causality at 5% levels and 1% levels respectively. In general, there exist bi-directional causality between real GDP and real productivity in the country whereas real wages seem to be not affected by them. This is not surprising as similar findings are found in OECD and G7 nations. Higher productivity stemming from education, retraining and research and development has help develop

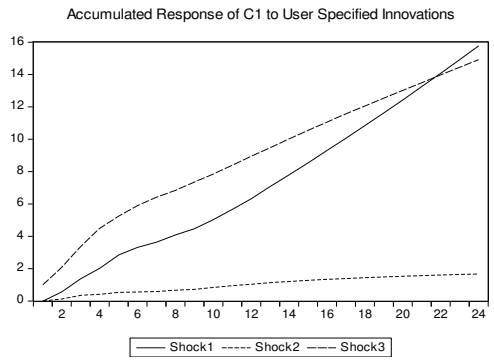
Singapore into a knowledge-based economy which drives economic growth. Since inflation has been relatively stable in the past decade, real GDP has risen in tandem. This success would encourage greater capital deepening and widening leading to greater multifactor productivity growth which is a factor of labor productivity. Real wages however seem to be explained more by external factors such as hiring conditions and government's wage policy. Thus, there exists a role for the government intervention when wages have fallen too low with respect to standard of living or too high with respect to global competitiveness.

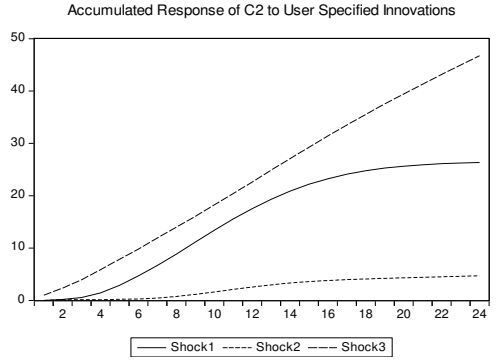
The manufacturing sector has the most inter-connected PWG nexus as causality runs bi-directionally between labor productivity and real GDP while both granger-cause real wage at 1% significance level. This suggests that policies should be administered to drive productivity or output growth in the sector as workers benefit from the rising wages. There also seem to be a credible wage structure in place in terms of individual performance-based pay as productivity growth has spilled onto higher incomes for workers. This paper thus lends support to schemes aimed at improving productivity in manufacturing put forth by the Singapore government.

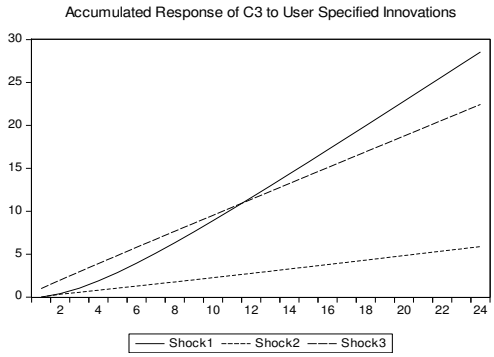
The construction sector however shows uni-directional causality between wages and productivity and GDP. This may suggest efficient wage hypothesis and that higher wages may lead to re-structuring of work processes and job-redesign leading to higher productivity in the sector. In this case, policy-makers may want to adopt a different strategy by encouraging construction firms to adopt a more lucrative wage structure for their employees while improving job efficiency by mechanisation. This is akin to a successful restructuring period in Sweden discussed extensively in Edin and Topel (1997). The other industries mainly reflect causality between real GDP and labor productivity which is even more prevalent at 10% significance level.

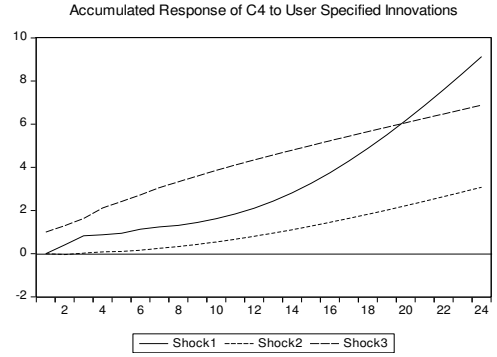
By understanding of the sectoral PWG nexus, this paper suggests different approaches to drive growth in the priority areas suggested by the National Productivity and Continuing Education Council (NPCEC). For electronics and engineering, driving productivity by training and deepening of knowledge and skills would be relevant. However, sectors such as construction, hotel and F&B may need to focus unlocking value-creation in jobs to allow for a wage increment which might better help drive productivity and economic growth.

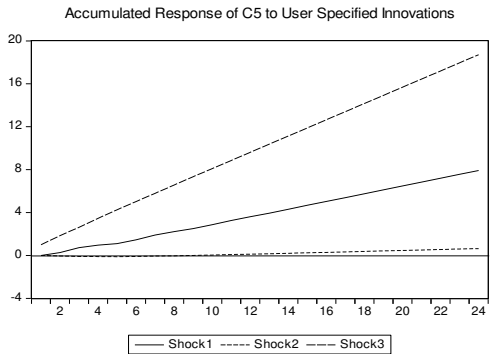
4.3 Impulse Response of Wages

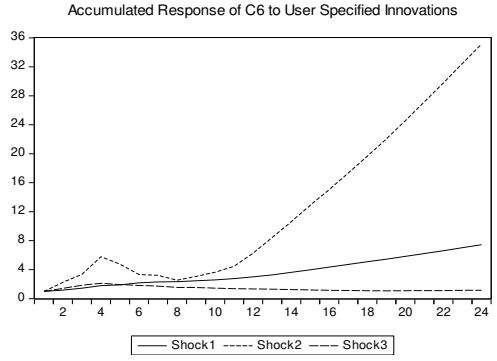












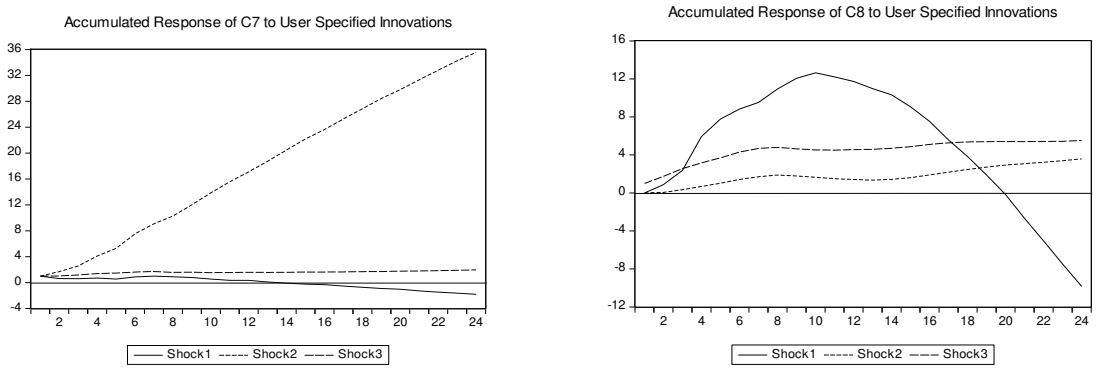


Figure 3.1 IRF to shock from LP (1), RGDP (2) and Real Wage (3)[14]

Figure 3.1 shows the impulse response of real wages to shocks from labor productivity and real GDP. The vertical axis represents the accumulated percentage change over a period of 24 quarters. These impulse responses are generated from cholesky decomposition with ordering of wages-growth-productivity and is similar to results from generalised impulses except for manufacturing where the ordering was reverse, supported by granger causality analysis where wages were caused by productivity and GDP instead.

In general, a 1% shock in GDP leads to a 3% growth in real wages while a 1% shock in productivity leads to a 10% growth in wages in 24 quarters. This shows that growing labor productivity and not real GDP may be the core impetus into the future if the government is aiming for inclusive growth. This would have repercussions on immigration policy, work processes and job-redesigns.

However, it is worth noting that this may not be true for the manufacturing sector as real output in the sector may influence real wages more. Moreover, labor productivity also seem to have a negative impact on wholesale and retail as time persist meaning that labor productivity growth may only help raise real wages in the short run. Lastly, from the storage, transport and info-communication sector, raising productivity of the same job may not be helpful as wages stagnate due to the substitution of workers by technology.

[14] The IRF are represented by 1 is business, 2 is construction, 3 is financials, 4 is whole economy, 5 is hotel and restaurant, 6is manufacturing, 7 is storage, transport and info-communication and 8 is wholesale and retail.

5.0 Conclusion and Extensions

This paper investigates the empirical relationship between labor productivity, real wages and real GDP in Singapore from 1997 to 2011. This is important as findings present various policy options for different industries in Singapore by using statistical methods backed with fundamental economic theories.

The main findings are as follows. First, PWG in Singapore has grown at different rates leading to increasing wage share and decreasing profit share. In general, real GDP moves in tandem with labor productivity but could be influenced by immigration policies and that wage growth in different sectors need not grow together with productivity. Second, there exist only bi-directional causality between real GDP and labor productivity with wages being granger-caused by other factors. However, wages in the manufacturing sector is in fact granger caused by labor productivity and real GDP. Thirdly, a 1% shock in labor productivity seems to influence wages more than a 1% shock in real GDP in the economy. Most importantly, a positive relationship is found present amongst them.

There are limitations to this paper that can help with the analysis once provided. First, employment data on labor turnover in different industry, once available, will allow one to further understand how many workers switch away from certain jobs and its impacts on real wages and real GDP. This helps policy-makers to understand whether certain jobs should be re-designed or out-sourced. Second, real wages would be better specified if full compensation including CPF contribution by employer, workfare and other benefits are also available. Lastly, one extension the author hopes to make into the future is to understand how a minimum wage could play a role in the PWG relationship in each industry. This could help guide future policy-makers become more incisive in wage policies.

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APPENDIX

Appendix A:

Applying Lucas (1988) growth model:

$$y = A(HuL)^{\alpha} k^{1-\alpha} \quad \text{(A1)} \qquad y = c + \dot{k} + wHuL \quad \text{(A2)} \qquad \frac{\dot{H}}{H} = m_1 - m_2 u \quad \text{(A3)}$$

$$A = aH^{b} \text{(A4)} \qquad \frac{\dot{w}}{w} = \delta_1 - \delta_2 u \quad \text{(A5)} \qquad \frac{\dot{c}}{c} = \sigma(r - \theta) \quad \text{(A6)}$$

where y, k, L, c, u total output, stock of capital, labor supply, capitalist consumption and share of employment in total labor supply. w, r, H and A are real wage, rate of return of capital, average labor productivity and external effect of productivity on worker. Parameters are assumed positive. Wage is paid to factor of production HuL. Using A1 to A6 and assuming marginal productivity condition equals marginal condition for effective labor, (2) is achieved.

Appendix B:

Johansen Cointegration

To perform Johansen's cointegration test, the VECM is estimated:

$$\Delta z_t = \Pi ect_{t-1} + \Gamma_1 \Delta z_{t-1} + ... + \Gamma_{k-1} \Delta z_{t-k+1} + e_t \qquad (B1)$$

where z contains PWG and Π contains information of the long run relationship. Π is decomposed into $\alpha\beta'$ where the former denotes speed of adjustment while the latter is the cointegrating vector. The Johansen method employs likelihood ratio test using the trace test or maximum eigenvalue test.

VAR Estimation

Assuming a VAR (p) model, $y_t = A_1 y_{t-1} + ... + A_p y_{t-p} + u_t$, we stack the T observations and thus $Y = A\dot{Y} + U$ where $Y = [y_1, ..., y_t]$, $\dot{Y} = [Y_0, ..., Y_{T-1}]$ and $A = [A_1, ..., A_p]$. Estimating by least squares, $\hat{A} = YY'(YY')^{-1}$.

VECM Estimation

Assuming a VECM (p) model, $\Delta y_t = \alpha\beta' ect_{t-1} + \Gamma_1 y_{t-1} + ... + \Gamma_{p-1} \Delta y_{t-p+1} + u_t$ can be written compactly into $\Delta Y = \alpha\beta' Y_{-1} + \Gamma \Delta \dot{X} + U$ where $\Delta Y = [\Delta y_t, ..., \Delta y_T]$, $Y_{-1} = [yo, ..., y_{T-1}]$,

$\Gamma = \left[\Gamma_{1,}....,\Gamma_{p-1}\right]$, $\Delta\dot{X} = \left[\Delta X_0,.....,\Delta X_{T-1}\right]$ and $\Delta X_{t-1} = \left[\Delta y_{t-1}'.....\Delta y_{t-p+1}'\right]$. Hence, by solving, $\Gamma(\alpha\beta') = (\Delta Y - \alpha\beta' Y_{-1})\Delta\dot{X}'(\Delta\dot{X}\Delta\dot{X}')^{-1}$.

Appendix C:

The cholesky decomposition uses the inverse of the cholesky factor of the residual matrix to orthgonalize the impulses. The ordering of variable is thus important in generating impulse response as it attributes all the effects of any common component to the variable that comes top in the VAR system.

The generalized impulse is best described by Pesaran and Shin (1998) as obtaining a set of innovations that does not depend on ordering. The generalized impulse of an innovation to the j-th variable is achieved by applying a variable specific cholesky factor computed with the j-th variable at the top of the ordering.

More technical details are found in Hamilton's Time Series Analysis.

Appendix D:

Results for Unit Root Test

Var.	Level	1st Diff	Var.	Level	1st Diff	Var.	Level	1st Diff
A1	-2.11	-7.21*	B1	-1.48	-6.85*	C1	-4.72*	-6.42*
A2	-2.29	-4.52*	B2	-1.96	-2.73	C2	-2.95	-5.02*
A3	-3.31	-4.53*	B3	-3.03	-5.66*	C3	-4.13*	-9.91*
A4	-1.93	-6.21*	B4	-2.60	-7.13*	C4	-3.62*	-11.0*
A5	-3.45	-7.58*	B5	-3.36	-8.17*	C5	-2.48	-8.35*
A6	-3.30	-8.37*	B6	-3.75*	-7.52*	C6	-2.94	-9.31*
A7	-0.76	-8.10*	B7	-2.33	-7.90*	C7	-3.92*	-12.4*
A8	-.1.14	-3.91*	B8	-1.66	-4.01*	C8	-2.44	-8.15*

The ADF test is applied in the above scenario and t-stats are reported. A, B and C represents labor productivity, real GDP and real wages respectively and 1, 2, 3, 4 ,5, 6, 7, 8 refers to business services, construction, financial service, whole economy, hotel and restaurant sector, manufacturing industry, storage-transport-info-communications and wholesale and retail services. Those with * are significant at 5% levels. For B2, unit root test of Elliott-Rothenberg-Stock DF-GLS shows that it is stationary in first difference.

Results for Cointegration, Number of Lag, Serial Correlation and Normality

Relation	Trace	Max. Eigen	Lag Order	SC. P-value	Nor. P-value
BS	1	1	4	0.66	0.81
CON	1	1	5	0.87	0.68
FS	1	0	1	0.11	0.03
ECON	0	0	2	0.91	0.00
HR	1	1	2	0.54	0.00
MANU	1	0	5	0.18	0.60
STIC	1	0	5	0.82	0.15
WR	1	1	5	0.24	0.16

All estimations are in VECM except for the whole economy which is estimated in VAR. The null of serial correlation in this case is no serial correlation while the null for normality is normality. Full models along with codes can be furbished upon request.