Stolper-Samuelson Time Series: Long Term US Wage Adjustment

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Factor prices adjust to product prices in the Stolper-Samuelson theorem of the factor proportions model. The present paper estimates adjustment in the average US wage to changes in prices of manufactures and services with yearly data from 1949 to 2006. Difference equation analysis is based directly on the comparative static factor proportions model. Factors of production are fixed capital assets and the labor force. Results have implications for theory and policy.

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The Stolper-Samuelson (SS, 1941) theorem concerns the effects of changing product prices on factor prices along the contract curve in the general equilibrium model of production with two factors and two products. The result is fundamental to neoclassical economics as relative product prices evolve with economic growth. The theoretical literature finding exception to the SS theorem is vast as summarized by Thompson (2003) and expanded by Beladi and Batra (2004). Davis and Mishra (2007) believe the theorem is dead due unrealistic assumptions. The scientific status of the theorem, however, depends on the empirical evidence.

The empirical literature generally examines indirect evidence including trade volumes, trade openness, input ratios, relative production wages, and per capita incomes as summarized by Deardorff (1984), Leamer (1994), and Baldwin (2008). There is evidence of the predicted wage convergence across trading partners in Tovias (1982), Gremmen (1985), Dollar and Wolff (1988), Mokhtari and Rassekh (1989), O'Rourke and Williamson (1992), and Rassekh (1992) as reviewed by Rassekh and Thompson (1993). Leamer and Levinshon (1995) and Leamer (1996) find evidence for rising wages in labor scarce developed countries. Rassekh and Thompson (1997) find support for the SS theorem in industrial countries controlling for model assumptions. Copeland and Thompson (2008) uncover evidence that falling import prices from 1974 to 1997 raise the US wage. Thompson (2009) finds evidence that energy input along with capital and labor affect the US wage.

The present paper estimates wage adjustments in the context of the SS theorem to changes in prices of manufactures and services with annual US data from 1949 to 2006. The relative price of services doubles during this period of increased international specialization and trade. Fixed capital assets and the labor force are exogenous variables in theory and the empirical analysis. The point of departure from theory is the reduced form wage equation from the comparative static factor proportions model.

The first section presents the estimating equation and background on the factor proportions model. The second section analyzes series stationarity. The third section presents the wage equation estimation. Results provide suggestions for policy as well as theory.

1. Stolper-Samuelson Wage Adjustments

The behavioral assumptions of the general equilibrium model of production are full employment and competitive pricing as developed by Samuelson (1953), Chipman (1966), and Takayama (1993). Production functions are homothetic with constant returns. Flexible factor prices ensure full employment with the focus on changing input levels. Outputs adjust as well as product prices change according to global competition.

The present application assumes two products, manufactures and services, with world prices P_M and P_S. The two factors of production are fixed capital assets K and the labor force L. The present paper relies on the algebraic comparative static model developed by Jones (1965) and Jones and Scheinkman (1977) with the wage w adjusting to changes in P_M and P_S as well as K and L.

Wage adjustments are solved as partial derivative comparative static changes relative to each of the exogenous variables. Signs of the SS theorem effects of P_M and P_S on w depend only on factor intensity. More critically perhaps, sizes of the SS effects depend on factor substitution as well. The change in the endogenous wage w can be summarized as a linear function of changes in each of the exogenous variables,

$$w' = \alpha_1 K' + \alpha_2 L' + \alpha_3 P_M' + \alpha_4 P_S' \quad (1)$$

where ' denotes percentage change. The α_i coefficients are partial derivatives cofactors of that element in the system matrix divided by the system determinant.

The SS theorem states α_3 and α_4 have opposite signs depending on factor intensity. Larger wage adjustments imply less substitution in production. These SS price coefficients are *ceteris paribus* elasticities that assume capital, labor, and price of the other product are constant.

2. Data and Stationarity Pretests

The SS difference equation suggested by (1) can be estimated if the series are difference stationary. The data are from the National Income and Product Accounts of the Bureau of Economic Analysis (2007). Price indices are from the Bureau of Labor Statistics (2007). The series are rescaled to one in 2006 for comparison in Figure 1. The variables have trends but appear difference stationary in Figure 2.

* Figure 1 * Figure 2 *

The average yearly wage w is derived from nominal total employee compensation averaged across the labor force L and deflated by the consumer price index. It has a positive trend over the 57 years but there are some flat years and a few decreasing years.

Capital K is the deflated net stock of fixed capital assets that generally increases at an increasing rate with some periods of linear growth and a few flat episodes. The labor force L is the civilian non-institutional population 16 years and older that increases at a slow steady rate.

Price indices for manufactures P_M and services P_S are deflated by the CPI. There is a slow steady increase in P_S and in stark contrast an accelerating decline in P_M. Over the entire period P_M decreases 59% while P_S increases 49%. In response, the output of services relative to manufactures increases by almost half as the economy moves along its expanding production frontier.

The autoregressive AR(1) tests in Table 1 indicate nonstationary series. The reported coefficient is α_1 plus twice its standard error in the AR(1) regression $y_t = \alpha_0 + \alpha_1 y_{t-1}$. The wage coefficient is close to one indicating very weak long term convergence.

* Table 1 *

Percentage changes in the wage $\Delta \ln w$ and price of services $\Delta \ln p_S$ are difference stationary by Dickey-Fuller (1979) DFc tests with a constant $\Delta y_t = \alpha_0 + \alpha_1 y_{t-1} + \varepsilon_t$. The α_1 coefficients are insignificant relative to the critical DF statistic -3.78 and F statistics are insignificant relative to the critical ϕ statistic 7.06. There is no evidence of residual correlation according to the critical Durbin-Watson statistic DW = 1.40 and no heteroskedasticity in residuals according to autoregressive conditional heteroskedasticity ARCH(1) tests.

The percentage change in the capital stock $\Delta \ln K$ has residual correlation in residuals of DF tests and ARCH(1) heteroskedasticity in the augmented Dickey-Fuller ADF test. Percentage changes in the labor force $\Delta \ln L$ and price of manufactures $\Delta \ln P_M$ have residual correlation in DF tests and significant ϕ statistics. ADF tests with additional lags produce similar results but these three series are difference stationary with a 1975 structural break by the Perron (1989) test in the last column. After the break in Figure 2, the $\Delta \ln K$ series becomes more active, $\Delta \ln L$ levels, and $\Delta \ln P_M$ becomes much more active and lower. The 1975 structural break is consistent with economic restructuring following the energy crisis.

3. Estimating the SS Wage Equation

There is the expected residual correlation in the unreported wage regression in levels of variables. Regressions with various lags of independent variables produce similar results. The series are weakly cointegrated according to the Engle-Granger test but there is no error correction process and the result is not reported. Attention focuses on the difference model where the coefficients of interest are almost identical to the error correction estimate.

The first row in Table 2 reports the estimated structural equation (1) in differences of natural logs,

$$\Delta \ln w = \alpha_0 + \alpha_1 \Delta \ln K + \alpha_2 \Delta \ln L + \alpha_3 \Delta \ln P_M + \alpha_4 \Delta \ln P_S + \varepsilon \qquad (2)$$

where ε is a white noise residual. The added constant α_0 allows other influences on the wage. There is no evidence of residual correlation according to Durbin-Watson statistic, and no evidence of heteroskedasticity according to the ARCH(1) test.

* Table 2 *

The 1975 oil price break dummy variable and its interaction terms are included in the difference regression but prove insignificant and are not reported. The coefficient estimates of interest are similar to those with the break only and with the various combinations of interaction terms separately.

Changes in capital and labor endowments affect the wage. Every 1% increase in fixed capital assets raises the wage 0.55% by increasing the marginal product of labor. Every 1% increase in the labor force lowers the wage -1.63% through increased supply. Immigration puts downward pressure on the wage. Prices of manufacturing and services have no wage effects. The positive α_0 indicates a 4.3% deterministic trend in the wage. Regressions with various one or two year lags of independent variables produce similar results.

The model with stationary residuals of the three Perron equations imbedding the structural break produces slightly stronger results in the second row of Table 2. A manufacturing price effect surfaces, and this regression is discussed as the main result. The difference stationary residuals of the Perron structural break regressions for Δln$L$, Δln$K$, and ΔlnP_m enter the difference regression. For instance, the Perron test $\ln L = a_0 + a_1 t + a_2 D + \varepsilon_P$ has a difference stationary residual ε_P and $\Delta\varepsilon_P = \Delta\ln L$. This Perron residual includes information on the 1975 break and the trend. Regressions with various lags of these Perron residual variables produce weaker results.

The capital stock K has a positive 0.51 wage elasticity, very similar to the difference equation estimate in the first row. The mean of Δln$K$ in the sample is 3.5% implying a typical yearly wage impact of 1.8%. The high 2.2% standard deviation of Δln$K$ suggests a range of capital stock changes from 5.7% to 1.3% with corresponding wage effects from 2.9% to 0.7%. The 3.5% average increase in the wage during the sample period is about half accounted for by investment.

The growing labor force L has a negative wage elasticity of -0.87 making labor is its own worst enemy. The mean Δln$L$ of 1.4% implies a typical wage decrease of -1.2%. Investment manages to slightly offset the negative effect of labor force growth. Consistent with the neoclassical growth model, the capital/labor ratio raises the wage. The 0.5% standard deviation of labor force growth suggests the continuous downward wage pressure ranges from -1.7% to -0.8%.

The price of manufactures P_M has a wage elasticity of 0.31. The mean and standard deviation of ΔlnP_M are -2.0% and 1.7% implying continuous downward wage pressure. The mean wage adjustment to the falling price of manufactures is -0.6% that ranges from -0.1% to -1.1% by one standard deviation. Regarding protection manufactures, the real wage would rise if the share of manufactures in consumption were under 31%.

The price of services P_S has no independent wage impact. The mean ΔlnP_S of 0.8% and its standard deviation of 0.9% are perhaps too small to impact the wage even though the service sector is a majority of the economy. The trend in P_S in Figure 1 is smooth and consistent but less dramatic than wage growth. Regressions with lags of ΔlnP_S reveal no wage effects. Regressions without ΔlnP_S result in nearly identical coefficients for other variables. The insignificant 0.24 elasticity would account for a typical yearly wage increase of only 0.2%.

The mean wage growth is 3.5% with a 2.5% standard deviation. The regression explains 35% of the wage variation. The three significant effects essentially cancel each other as the effect of increased capital just offsets labor growth and the falling manufactures price. The insignificant effect of the price of services would account for a wage increase of only 0.2%.

Changing factor endowments within a production cone should produce no effects on the wage. It may be that the production cone has shifted due to technology although the white noise residuals do not suggest trends or breaks in technology. Other possible reasons for the endowment effects include issues with the data series, distortions due to aggregation, technical issues such as returns to scale or homotheticity, and other factors of production as developed by Thompson (2010) for energy input.

4. Conclusion

The falling price of manufactures in the US over six decades has had a small but consistently negative wage effect holding constant fixed capital assets, the labor force, and the price of services. Import protection that succeeds in raising the price of manufactures, however, would generate no noticeable effect on the real wage, reduce national income, and invite foreign retaliation.

Investment in fixed capital assets has a noticeable wage impact. Increases in the labor force lower the wage. These two results together support the neoclassical growth model with the rising capital labor ratio increasing the wage. Two policies to raise the wage are reduced capital taxes and limits on immigration.

The present direct time series approach to estimating the comparative static factor proportions model can be applied to other countries, regions, historical episodes, data frequencies, and aggregations of inputs and outputs. The numerous assumptions in the theoretical literature regarding imperfect competition in product and factor markets can be specified and tested directly. Systems of equations based can be simultaneously estimated and the various technical restrictions tested. Higher dimensional models with less aggregated inputs and outputs can be estimated.

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Table 1. Stationarity Analysis

	AR(1)	DF	DFc	DFt	ADF	Perron 1975
lnw	1.02 > 1	5.76	-2.44			
ϕ			5.95			
DW			1.68			
ARCH(1)			0.42			
lnK	1.01 > 1	11.3	-0.95	-1.24	-1.97	-1.79
ϕ			0.89	1.07	6.21	
DW			1.13*	1.11*	1.87	1.97
ARCH(1)					2.97*	1.27
lnL	1.00 > 1	21.6	-0.23	-0.49	-1.28	-2.43
ϕ			0.05	0.20	11.2*	
DW			0.79*	0.79*		1.87
ARCH(1)						0.94
$\ln P_M$	1.03 > 1	-3.60*	5.59	1.03	0.99	-0.48
ϕ				15.4*		
DW						1.78
ARCH(1)						0.99
$\ln P_S$	1.01 > 1	-5.71*	-0.95			
ϕ			0.91			
DW			1.82			
ARCH(1)			0.36			
τ_{DF}		-2.62	-3.58	-4.15	-4.15	τ_{Perron}
ϕ				7.02	7.02	-3.76
DW 1.40						

Table 2. The Wage Difference Equation (3)

	Δlnw	Constant	ΔlnK	ΔlnL	$\Delta \ln p_M$	$\Delta \ln p_S$
	R^2 .353 DW 1.70 ARCH(1) -0.47	0.04** (3.17)	0.55*** (2.59)	-1.63*** (-2.06)	0.16 (0.55)	0.40 (1.14)
Perron model	R^2 .346 DW 1.74 ARCH(1) -1.14	0.03*** (7.90)	0.51*** (3.64)	-0.87*** (-1.98)	0.31** (1.82)	0.24 (0.69)

Figure 1. Data series

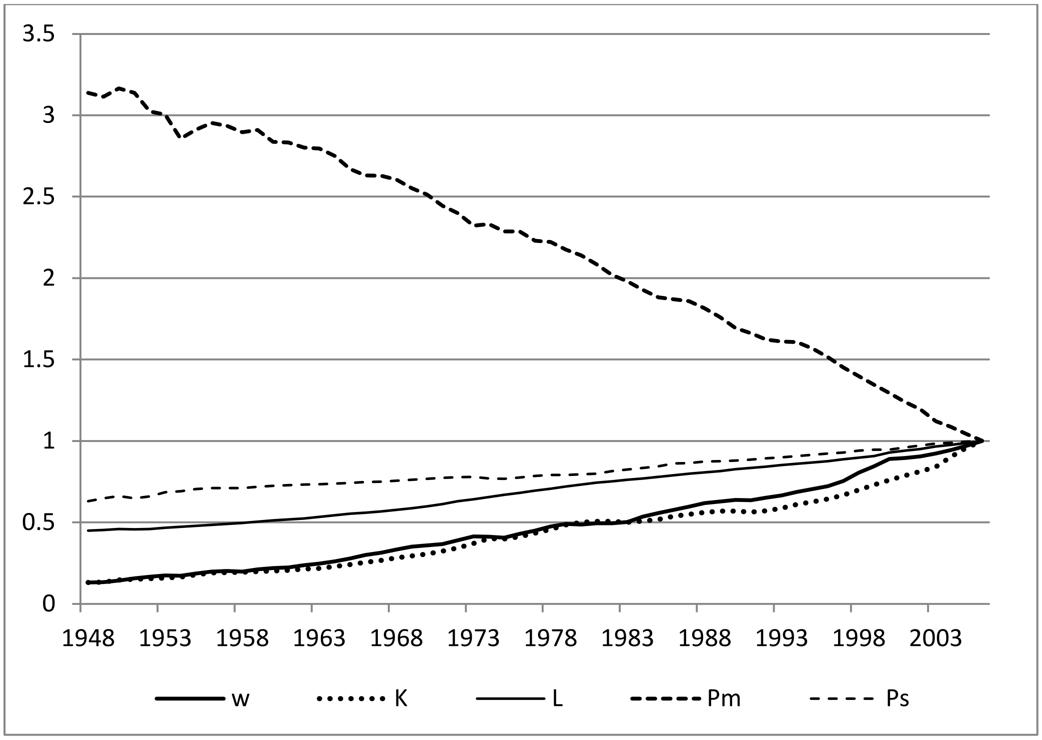

Figure 2. Data Differences