Wages in a Factor Proportions Model with Energy Input*

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Abstract

This paper examines US wage adjustment in a structural vector autoregression of the factor proportions model with capital, labor, and energy inputs. Data cover the years 1949 to 2006. The wage adjusts to changes in inputs levels and output prices over six to eight years. Energy has a more robust wage impact than capital. The wage reacts weakly if at all to the falling price of manufactures and rising price of services during the sample period. Estimates relate directly to factor proportions theory suggesting robust substitution with labor in the middle of the factor intensity ranking.

Keywords: Wages; Energy; Factor Proportions Model; Vector Autoregression

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I. Introduction

The present paper estimates US wage adjustments in a factor proportions model with capital, labor, and energy inputs and yearly data from 1949 to 2006. Data include the average wage, fixed capital assets, labor force, Btu energy input, and prices of manufactures and services. Structural vector autoregressions estimate dynamic wage adjustments to exogenous shocks in endowments and product prices. The SVAR model is motivated by wage "stickiness" due to labor market contracts and the minimum wage.

The empirical literature on wage convergence generally focuses on the level of trade as suggested by factor proportions models. This literature reviewed by Rassekh and Thompson (1998) includes Tovias (1982), Gremmen (1985), Dollar and Wolff (1988), Mokhtari and Rassekh (1989), O'Rourke and Williamson (1992), Rassekh (1992), Leamer and Levinshon (1995), and Leamer (1996). The present paper takes a more direct approach to the Stolper-Samuelson theorem by linking wages to product prices rather than the level of trade.

Rassekh and Thompson (1997) uncover some support for the Stolper-Samuelson theorem across industrial data. Thompson (2011, 2012) estimates the Heckscher-Ohlin model and the Stolper-Samuelson theorem with capital and labor inputs for US time series. The present paper relates to the error correction estimates of Thompson (2010) extending the wage adjustment period and uncovering stronger wage adjustments in the SVAR estimates.

The US has specialized toward services due to falling prices for wide range of manufactured goods during the nearly six decades of the present sample. Wage effects

along the contract curve moving toward services depend on factor intensity and substitution. The evidence suggests robust substitution among capital, labor, and energy inputs. Results are consistent with labor in the middle of the factor intensity ranking. Energy input has a stronger effect on the wage than does capital. Empirical wage studies that do not include energy input suffer misspecification error.

The following section presents the theory followed by a section on the SVAR model and data pretests. Results are then presented followed by a discussion of policy implications in the Conclusion.

II. Wages in the Factor Proportions Model

The factor proportions model assumes full employment, competitive pricing, cost minimization, and neoclassical constant returns production functions. The literature grew based on the writings of Heckscher (1919) and Ohlin (1933) into the algebraic model of Stolper and Samuelson (1941), Jones (1965), Chipman (1979), and Takayama (1982). The model provides the core theorems of international trade theory.

The present application has two products, manufactures M and services S. Inputs of capital K and labor L would imply input levels have no wage impacts in the factor price equalization property of Lerner (1952) and Samuelson (1948). Empirical analysis along the present lines, however, uncovers robust wage effects with only K and L inputs. Adding energy E to capital and labor leads to a theoretical model consistent with the present empirical results. Energy proves to have a more robust effect on the wage than capital in

the present data. The related factor proportions model with three inputs is developed by Ruffin (1981), Jones and Easton (1983), and Thompson (1985).

The two major behavioral assumptions of the factor proportions model are full employment and competitive pricing. Full employment is stated $v_i = \Sigma_j a_{ij} x_j$ where v_i is the available level of input i, a_{ij} is the cost minimizing input of factor i per unit of product j, and x_j is the level of output. Inputs are capital, labor, and energy, $i = K, L, E$. Outputs are manufactures and services, $j = M, S$. Differentiate the full employment condition and introduce factor cost shares θ_{Lj} and substitution elasticities σ_{ik} between the price of factor k and input of factor i to derive the first three equations in the comparative static system (1) below. Own price substitution elasticities σ_{ii} are negative. Cross price substitution terms σ_{ij} are positive for substitutes but one pair of inputs may be complements.

Competitive pricing of product j is written $p_j = a_{Lj}w + a_{Kj}r + a_{Ej}e$ where p_j is price. Input prices are the wage w, capital rent r, and the price of energy e. Differentiate and utilize the cost minimizing envelope theorem to derive the last two equations in (1) where industry share λ_{ij} is the portion of factor i employed in sector j.

This 3x2 comparative static factor proportions model stated in differences is

$$\begin{pmatrix} \sigma_{LL} & \sigma_{LK} & \sigma_{LE} & \theta_{LM} & \theta_{LS} \\ \sigma_{KL} & \sigma_{KK} & \sigma_{KE} & \theta_{KM} & \theta_{KS} \\ \sigma_{EL} & \sigma_{EK} & \sigma_{EE} & \theta_{EM} & \theta_{ES} \\ \lambda_{LM} & \lambda_{KM} & \lambda_{EM} & 0 & 0 \\ \lambda_{LS} & \lambda_{KS} & \lambda_{ES} & 0 & 0 \end{pmatrix} \begin{pmatrix} \Delta\ln w \\ \Delta\ln r \\ \Delta\ln e \\ \Delta\ln x_M \\ \Delta\ln x_S \end{pmatrix} = \begin{pmatrix} \Delta\ln v_L \\ \Delta\ln v_K \\ \Delta\ln v_E \\ \Delta\ln p_M \\ \Delta\ln p_S \end{pmatrix}. \qquad (1)$$

The system matrix is the Hessian of the constrained income maximization implying a negative determinant D as shown by Chang (1979). Solve (1) for wage effects with Cramer's rule to find

$$\varepsilon_{wL} \equiv \Delta \ln w / \Delta \ln v_L = \theta_{KE}\lambda_{KE}/D \tag{2}$$

$$\varepsilon_{wK} \equiv \Delta \ln w / \Delta \ln v_K = -\theta_{LE}\lambda_{KE}/D$$

$$\varepsilon_{wE} \equiv \Delta \ln w / \Delta \ln v_E = \theta_{LK}\lambda_{KE}/D$$

$$\varepsilon_{wM} \equiv \Delta \ln w / \Delta \ln p_M = (\lambda_{KS}\varphi_1 - \lambda_{ES}\varphi_2)/D$$

$$\varepsilon_{wS} \equiv \Delta \ln w / \Delta p_S = (\lambda_{EM}\varphi_2 - \lambda_{KM}\varphi_1)/D\ ,$$

where

$$\theta_{KE} \equiv \theta_{KM}\theta_{ES} - \theta_{EM}\theta_{KS}$$

$$\theta_{LE} \equiv \theta_{LM}\theta_{ES} - \theta_{EM}\theta_{LS}$$

$$\theta_{LK} \equiv \theta_{LM}\theta_{KS} - \theta_{LS}\theta_{KM}$$

$$\lambda_{KE} \equiv \lambda_{KM}\lambda_{ES} - \lambda_{EM}\lambda_{KS}$$

$$\varphi_1 \equiv (\theta_{KE} - \theta_{LK})\sigma_{LE} - (\theta_{LE} + \theta_{LK})\sigma_{KE}$$

$$\varphi_2 \equiv (\theta_{KE} + \theta_{LE})\sigma_{LK} + (\theta_{LK} + \theta_{LE})\sigma_{EK}\ .$$

The own labor elasticity ε_{wL} is negative since θ_{KE} and λ_{KE} have the same sign and $D < 0$. Factor intensity determines the signs of θ_{KE}, θ_{LE}, θ_{LK}, and λ_{KE}. One implication of factor intensity is that either ε_{wK} or ε_{wE} must be positive, but one could be negative.

The present estimates suggest labor is the middle factor in the factor intensity ranking

$$\theta_{EM}/\theta_{ES} > \theta_{LM}/\theta_{LS} > \theta_{KM}/\theta_{KS}, \tag{3}$$

given that manufactures is energy intensive relative to services. The factor intensity ranking in (3) implies $\theta_{KE} < 0$, $\theta_{LE} < 0$, $\theta_{LK} > 0$, and $\lambda_{KE} < 0$ consistent with direct evidence of similar factor shares in Thompson (1990, 1995).

Manufactures is energy intensive relative to capital and labor, and labor intensive relative to capital. Services includes real estate and business services making it capital intensive relative to labor. The positive ε_{wE} in the estimates suggests manufactures is labor intensive and energy intensive relative to capital, $\theta_{LK} > 0$ and $\lambda_{KE} > 0$. Signs of the price effects on the wage in the estimates of ε_{wM} and ε_{wS} depend on factor intensity and substitution as do sizes of all wage elasticities.

Collating the partial derivative wage effects in (2) leads to the single equation

$$\Delta \ln w = (\lambda_{KE}(\theta_{KE}\Delta \ln v_L - \theta_{LE}\Delta \ln v_K + \theta_{LK}\Delta \ln v_E) - \varphi_M \Delta \ln p_M + \varphi_S \Delta \ln p_S)/D \qquad (4)$$

where $\varphi_M \equiv \lambda_{KS}\varphi_1 + \lambda_{ES}\varphi_2$ and $\varphi_S \equiv \lambda_{EM}\varphi_2 - \lambda_{KM}\varphi_1$. The empirical specification of (4) is

$$\Delta \ln w = \alpha_0 + \alpha_1 \Delta \ln v_L + \alpha_2 \Delta \ln v_K + \alpha_3 \Delta \ln v_E + \alpha_4 \Delta \ln p_M + \alpha_5 \Delta \ln p_S + \varepsilon, \qquad (5)$$

adding the constant α_0 and white noise residual ε. Theory specifies a negative α_1 due to concavity of the cost function. Either capital or energy must raise the wage implying at least one positive sign for α_2 or α_3. Price elasticities of the wage α_4 and α_5 have the four possible sign patterns in Thompson (1985).

Substitution diminishes these wage effects but does not affect directions of adjustments to input changes. Signs and sizes of price effects depend on factor intensity and substitution. Price changes shift outputs along the contract curve as the cost minimized

inputs adjust. Labor in the middle of the factor intensity ranking (3) suggests p_M and p_S have positive wage effects similar to the specific factors model.

III. The VAR Model and Data Pretests

Estimating the factor proportions wage effects in (5) with least squares is robust to specification errors but there are a number of empirical issues. Least squares coefficients would be inefficient with a serially correlated residual. The wage may be persistent. Estimates could be biased since factor proportions theory assumes exogenous right hand variables but endogeneity could be an issue. Feedback among variables is likely. Finally, structural interpretations for the error term in (5) are difficult without distinguishing sources of shocks, making policy implications a challenge.

These empirical issues motivate the structural vector autoregression SVAR model,

$$\Delta y_t = A(L)\Delta y_{t-1} + Cu_t \qquad (6)$$

where $y_t = [\ln w, \ln L, \ln K, \ln p_M, \ln p_S, \ln E]'$ is the vector of difference stationary variables, $A(L) = A_1 L + \cdots + A_k L^k$ is a lag polynomial, u_t is a vector of corresponding structural shocks, and C is the contemporaneous matrix. Detrending the present variables eliminates deterministic terms.

Consider orthogonalized structural shocks with unit variances $E u_t u_t' = I$ and $E(Cu_t u_t' C') = CC' = \Sigma$ where I is the identity matrix and Σ is the variance-covariance matrix from the least squares estimation of (6). The conventional method of Sims (1980) just-identifies the system (6). That is, assuming that C is a lower triangular matrix C is uniquely

identified by the Choleski decomposition of the least squares variance-covariance matrix estimate that is symmetric and positive definite. The impulse response function of the level variables is obtained by $y_t = \Sigma_{j=1}^{k+1}\Gamma_j y_{t-j} + Cu_t$ where $\Gamma_1 = I + A_1$, $\Gamma_j = A_{j+1} = A_j$, $j = 2,\ldots,k$, and $\Gamma_{k+1} = -A_k$. Long term responses of level variables are measured by $(I - A(1))^{-1}C$ and short term responses by C.

Estimates may not be robust to the variable ordering. While the generalized impulse response analysis proposed by Pesaran and Shin (1998) is free from this ordering problem, Kim (2012) shows it yields response functions based on contradictory assumptions that may lead to misleading inferences.

The ordering of (6) starts with world prices p_S and p_M assumed contemporaneously unaffected by domestic variables. The price of services p_S is ordered first assuming it is stickier than p_M. The service sector dominates the US economy and includes internationally competitive business services. Labor input L is ordered next based on the assumption that it is not affected by capital or energy inputs due to labor contracts. Capital would be contemporaneously unaffected by energy input and is ordered next. Finally, the endogenous wage w is ordered last assuming contemporaneous effects from all other variables. Robustness checks with alternative orderings yield qualitatively similar estimates.

Data are from the National Economic Accounts of the Bureau of Economic Analysis (2007) except Btu energy input that is from the Department of Energy (2007). The wage w is employee compensation averaged across the labor force L. The capital stock

K is the net stock of fixed capital assets. Both w and K are deflated by the consumer price index. Energy input E is total Btu input. The demeaned series are shown in Figure 1.

* Figure 1 *

The labor force L trends upward in a smooth fashion. The capital stock K also trends upward but with much more irregularity. Energy input E trends erratically upward with an apparent break and slower growth following the energy crises from the middle 1970s to early 1980s.

Prices of manufactures p_M and services p_S are indices relative to the CPI. The price of manufactures p_M falls at an increasing rate as the price of services p_S rises steadily. Import competition accounts for some part of the 68% decrease in p_M. Meanwhile p_S increases 59% during the sample period. The relative price of services p_S/p_M increases five times as the output of services relative to manufactures increases by about half.

The differenced series in Figure 2 appear stationary. Table 1 reports conventional augmented Dickey-Fuller ADF pretests for the six y_t variables in (6). The number of lags is based on the general-to-specific rule of Hall (1994) as recommended by Ng and Perron (2001). Tests begin with a maximum three lags of differenced variables in the ADF regression. If the last entry is insignificant at the 5% level, it is omitted. The same regression is repeated until the last entry becomes significant.

* Figure 2 * Table 1 *

The ADF test with an intercept accepts the null hypothesis of a unit root for all variables. The ADF test with an intercept and time trend also fails to reject the null for all variables. ADF tests strongly reject the unit root null for differenced variables both with an intercept and intercept plus time trend, consistent with difference stationary variables. The DF-GLS test proposed by Elliott, Rothenberg, and Stock (1996) leads to the same results with an exception for differenced *L* when trend is present. Cointegration is not considered because pretests are sensitive to normalization of the cointegrating equation.

IV. Factor Proportions VAR Wage Estimates

Table 2 presents the VAR estimates for the contemporaneous matrix C. Standard errors are obtained from 10,000 nonparametric bootstrap simulations. Capital *K* and especially energy *E* have strong short term wage effects while labor *L* has an insignificant contemporaneous own effect.

*Table 2 *

Both prices p_M and p_S have insignificant wage effects although the effect of the manufactures price is somewhat stronger. The magnification effect of Jones (1965) analyzed by Thompson (1993) in the three factor model suggests insignificant wage effects when labor is in the middle of the factor intensity ranking as in (3).

The long term wage effects of structural shocks given by $(I - A(1))^{-1}C$ with bootstrap standard errors after normalization are reported in Table 3. The effect of capital

K on the wage is insignificant in the long term. The labor force *L* has a significant negative effect on the wage. A 1% initial increase in *L* lowers the wage immediately as shown in Figure 4. This wage effect accumulates and converges to -5.4% over eight years.

* Table 3 * Figure 4 *

The positive effect of energy *E* on the wage is apparent in Figure 4. The energy effect is stronger than the capital effect as shown by the tighter confidence band. An increase of 1% in energy input raises the wage 0.7% contemporaneously. The effect increases over the next two years to over 1% and converges to 0.9% over six years.

An increase in the energy price *e* lowers energy input and the wage. Taxes or tariffs on energy would lower the wage as would a higher price of energy on the international market. This result supports Mountain (1986) who finds higher energy prices lowered the wage in Ontario especially during the energy crisis of the late 1970s. In contrast, Nasseh and Elyasiani (1984) find higher energy prices led to substitution toward labor in the US, Canada, UK, Germany, and France during the late 1970s.

Wage responses to inputs imply labor is in the middle of intensity ranking as in (3) and suggest robust substitution. Labor groups rightly opposed to immigration should also support policy friendly to energy input.

The 1.3% long-run wage responses to a shock in the price of services are larger than for the manufactures price. Both price effects converge after six years. If services were labor intensive, the p_S elasticity would be greater than 1 and the p_M elasticity negative. The present insignificant price effects suggest labor is middle factor. The weak price effects

imply relatively flat contract curves with robust substitution as illustrated by Ford and Thompson (1997). The large output adjustments during the sample period are also evidence suggesting strong substitution.

Tariffs on manufactures that would raise the wage are unsuccessful in the model. An increase of 10% in the price of manufactures might raise the wage 3.2% based on the insignificant point estimate. At any rate, that much of an increase in price is beyond the range of protection. Even then, the purchasing power of labor would fall if the manufactures share of consumption were over 32%. The bottom line is that labor has little interest supporting protection of manufactures.

Free trade leading to a higher price of services would be more successful in raising the wage. Tighter immigration policy would raise the wage. A 1% decrease in the labor force, within range of current immigration laws, would raise the wage 5.4% based on the point estimate with the 90% confidence interval [-10.40, -1.05].

The wage reacts to its own shocks from influences outside the model. A 1% wage shock results in a 0.7% wage increase over eight years. Other variables, especially labor, react positively to their own shocks. Labor and the price of manufactures do not react to other variables, consistent with assumed exogeneity.

Energy input responds negatively to the wage. Capital has positive responses to shocks in energy input and the price of services. The price of services falls with capital and labor inputs, but increases with the wage. Energy input stimulates investment rather than vice versa, suggesting economic growth is heavily dependent on energy. Misspecification

of a wide range of applied growth models is an issue. A positive labor force shock lowers the wage and the price of services.

The present results relate directly to the error correction estimates of Thompson (2010) where wage adjustments occur over two to three years. The present energy and capital effects are similar in immediacy and size. The present labor force effects are about twice as strong over the longer adjustment period of six to eight years. The positive effect of the price of services is similar. The price of manufactures has no effect in the present estimates but a weak negative effect in the error correction estimate.

Variance decomposition analysis in Table 4 reveals that energy plays a role in affecting the variance of *k*-step-ahead wage forecast errors. Capital input and the wage explain significant portions of total variations only up to two years. Labor input explains a significant portion of the wage variance only over more years. The contributions of prices to the variance of the wage are insignificant, consistent with the SVAR specification.

* Table 4 *

V. Conclusion

The present results have a wide range of policy implications for the US economy. The insignificant effects of prices of manufactures and services on the wage suggest there is robust substitution with labor in the middle of the factor intensity ranking. Tariffs on imported manufactures lower the purchasing power of labor. Further, a rising price of exported services due to free trade might raise the wage. The long term trends of the falling

price of manufactures and rising price of services raise the wage. Labor groups would be wise to shun protectionism that may only benefit owners of industry capital.

Slower growth of the labor force would strongly raise the wage suggesting labor groups should favor enforcing immigration laws. Reduced capital taxes would also raise the wage. Even more critical, reduced energy taxes would have a positive impact on the wage. Labor productivity benefits from both capital and energy inputs but much more from energy.

The present approach to directly estimate the reduced form equations of the factor proportions model widens its scope of application. Future research can estimate adjustments in the wage and other endogenous variables for other countries and time periods. Different specifications can disaggregate labor, add other inputs, and separate outputs. Various industrial structures and factor market assumptions can be tested. The price of energy can be assumed exogenous for small price taking economies with endogenous energy imports. Comparing estimates across countries would reveal influences of legal systems, industrial structure, and labor market institutions.

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Table 1. Unit Root Pretests

Variable		ADF_c	$ADF_{c,t}$	$DF-GLS_c$	$DF-GLS_{c,t}$
w	Level	-2.277	-2.656	0.712	-1.856
	Differenced	-5.571‡	-5.704‡	-4.881‡	-5.417‡
K	Level	-0.990	-1.968	0.885	-1.717
	Differenced	-4.654‡	-4.683‡	-4.068‡	-4.426‡
L	Level	-2.218	-1.624	-0.001	-1.368
	Differenced	-2.994†	-3.155§	-2.055†	-2.324
p_M	Level	5.591	1.028	1.399	-0.137
	Differenced	-3.178†	-7.292‡	-2.866‡	-7.250‡
p_S	Level	0.250	-1.235	2.291	-1.351
	Differenced	-6.869‡	-6.895‡	-2.232†	-5.574‡
E	Level	-2.647	-1.535	0.595	-0.848
	Differenced	-5.537‡	-6.166‡	-4.632‡	-6.151‡

Note: The number of lags is selected by the general-to-specific rule of Hall (1994) following Ng and Perron (2001) for the ADF test. We used the same number of lags for the DF-GLS test. ADF_c ($DF\text{-}GLS_c$) and $ADF_{c,t}$ ($DF\text{-}GLS_{c,t}$) refer the ADF-*t* (*DF-GLS*) statistics when an intercept is included and when an intercept and time trend are included. Superscripts § † ‡ indicate the null of unit root is rejected at 10%, 5%, and 1% levels. Asymptotic critical values are from Harris (1992).

Table 2. Contemporaneous Matrix Estimates

$$\varepsilon_t^{ps} = u_t^{ps}$$

$$\varepsilon_t^{pm} = \underset{(0.398)}{-0.022} u_t^{ps} + u_t^{pm}$$

$$\varepsilon_t^{L} = \underset{(0.155)}{0.158} u_t^{ps} - \underset{(0.031)}{0.004} u_t^{pm} + u_t^{L}$$

$$\varepsilon_t^{K} = \underset{(0.493)}{1.056} u_t^{ps} + \underset{(0.162)}{0.292} u_t^{pm} + \underset{(0.607)}{0.413} u_t^{L} + u_t^{K}$$

$$\varepsilon_t^{E} = \underset{(0.661)}{0.508} u_t^{ps} + \underset{(0.283)}{0.590} u_t^{pm} + \underset{(0.958)}{0.385} u_t^{L} + \underset{(0.226)}{0.467} u_t^{K} + u_t^{E}$$

$$\varepsilon_t^{w} = \underset{(0.773)}{0.878} u_t^{ps} + \underset{(0.256)}{0.362} u_t^{pm} - \underset{(1.138)}{1.180} u_t^{L} + \underset{(0.191)}{0.539} u_t^{K} + \underset{(0.095)}{0.709} u_t^{E} + u_t^{w}$$

Note: Standard errors are in parentheses and obtained from 10,000 nonparametric bootstrap simulations.

Table 3. Long Term Effect Estimates

	u_t^S	u_t^M	u_t^L	u_t^K	u_t^E	u_t^w
p_S	0.749*	-0.037	-1.288*	-0.176*	-0.077	0.153
	(0.311)	(0.101)	(0.637)	(0.087)	(0.058)	(0.098)
p_M	0.011	0.949*	0.368	-0.007	-0.156	-0.251
	(0.609)	(0.177)	(1.227)	(0.164)	(0.110)	(0.186)
L	0.156	-0.117	2.772*	0.084	0.046	0.001
	(0.527)	(0.158)	(0.923)	(0.126)	(0.084)	(0.147)
K	2.512*	-0.540	3.446	1.464*	0.520*	-0.499
	(1.270)	(0.464)	(2.943)	(0.401)	(0.259)	(0.443)
E	0.850	0.456	-0.529	0.111	1.107*	-0.637*
	(0.959)	(0.424)	(2.302)	(0.376)	(0.203)	(0.338)
w	1.281	0.322	-5.433*	0.452	0.920*	0.733*
	(1.559)	(0.517)	(2.898)	(0.418)	(0.252)	(0.435)

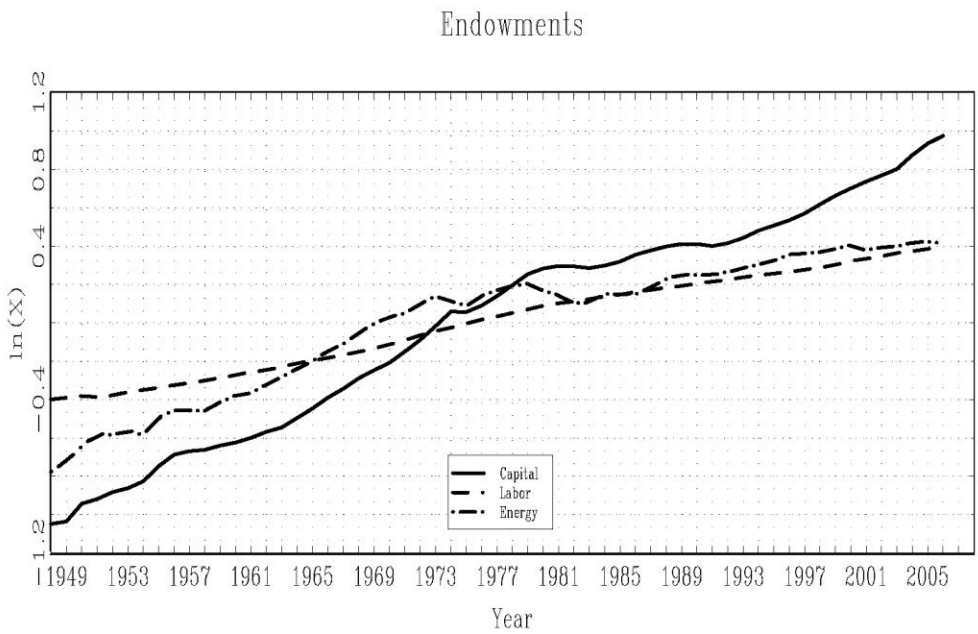
Note: Standard errors are in parentheses and obtained from 10,000 bootstrap simulations. * indicates that the estimate is significant at the 10% level.

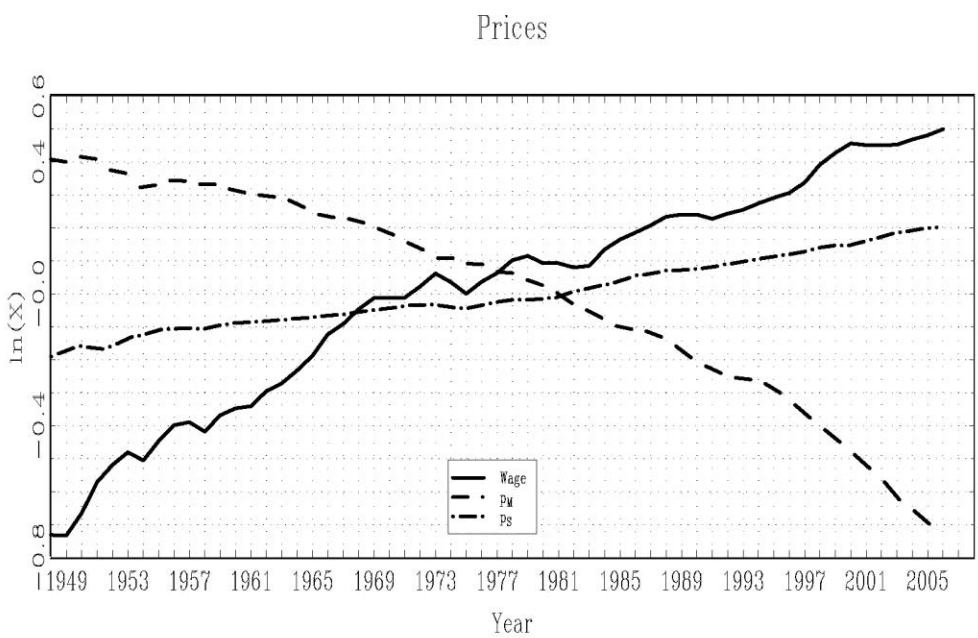
Table 4. Variance Decomposition of *k*-Step ahead Forecast Error

k	p_S	p_M	L	K	E	w
1	0.038	0.044	0.036	0.119	0.437	0.325
	(0.068)	(0.066)	(0.064)	(0.088)	(0.103)	(0.067)
2	0.046	0.016	0.106	0.145	0.534	0.153
	(0.088)	(0.062)	(0.103)	(0.106)	(0.131)	(0.076)
4	0.064	0.007	0.228	0.084	0.536	0.080
	(0.105)	(0.064)	(0.161)	(0.102)	(0.155)	(0.086)
6	0.050	0.013	0.334	0.053	0.455	0.094
	(0.101)	(0.071)	(0.193)	(0.093)	(0.161)	(0.088)
8	0.045	0.018	0.378	0.049	0.415	0.096
	(0.099)	(0.074)	(0.204)	(0.091)	(0.163)	(0.087)
10	0.045	0.018	0.393	0.047	0.404	0.094
	(0.099)	(0.074)	(0.209)	(0.091)	(0.165)	(0.087)

Note: Standard errors are in parentheses and obtained from 10,000 bootstrap simulations.

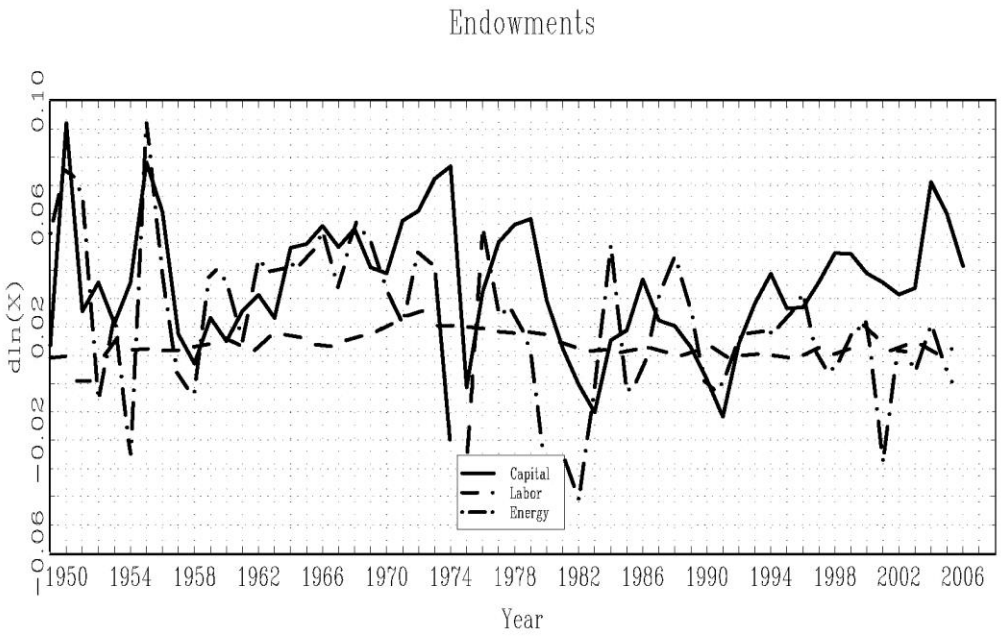
Figure 1. Data series





Note: Each series is demeaned.

Figure 2. Differenced Series



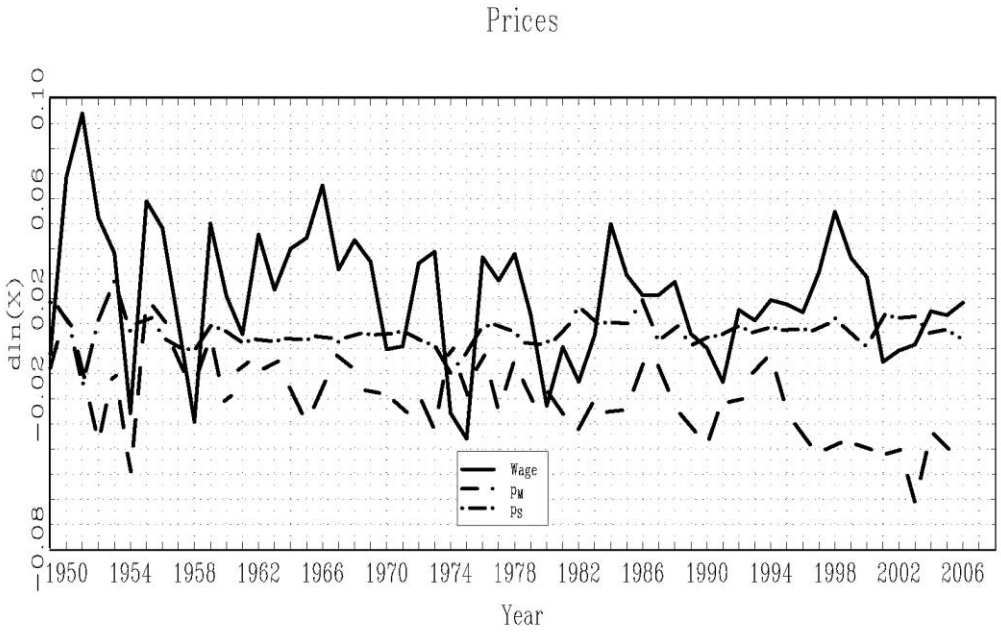
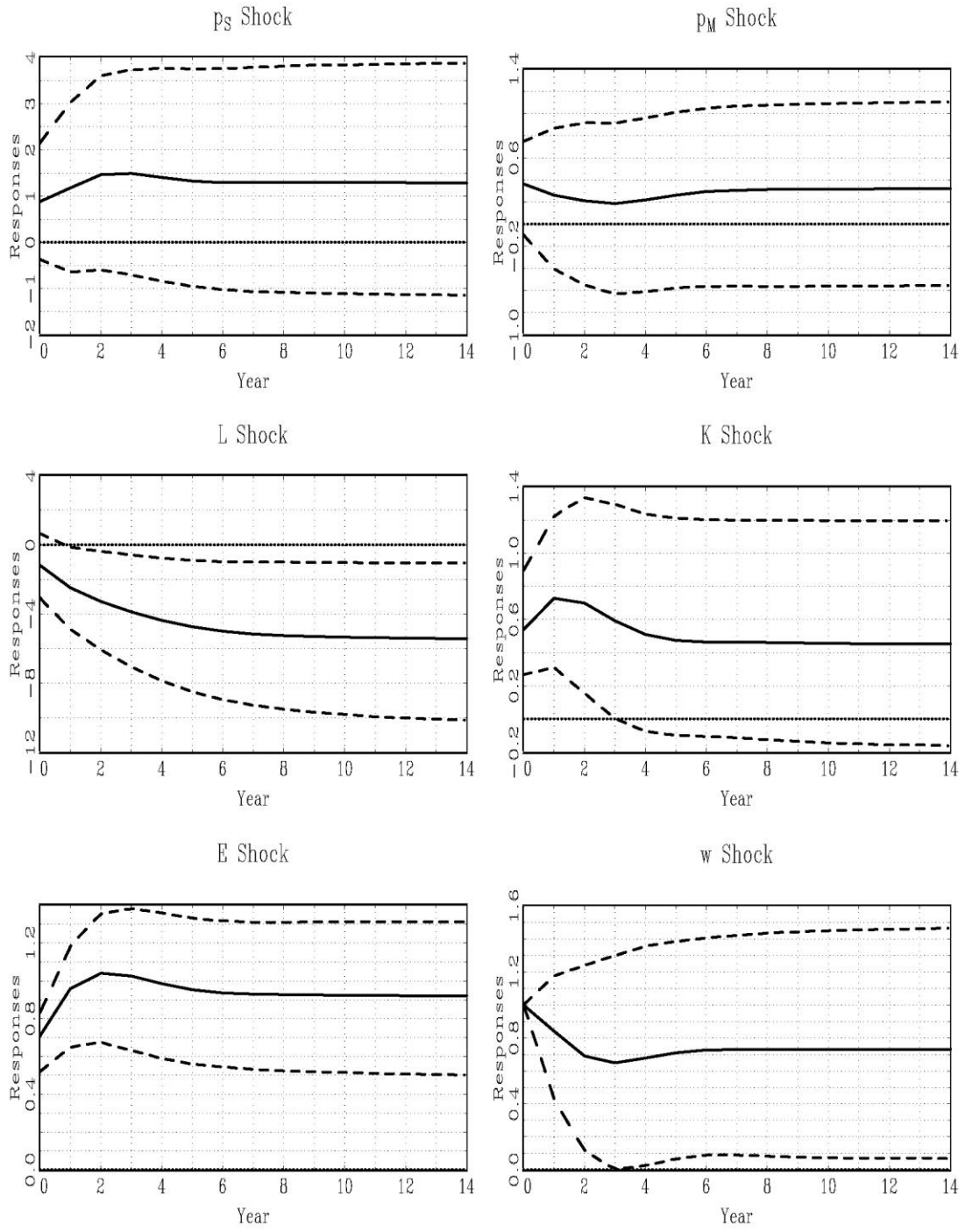


Figure 3. Wage Response Function Estimates



Note: The 90% confidence bands (dashed lines) are from 10,000 residual based nonparametric bootstrap simulations following Efron and Tibshirani (1993).