Modeling Electricity Demand in the Philippines

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Outline

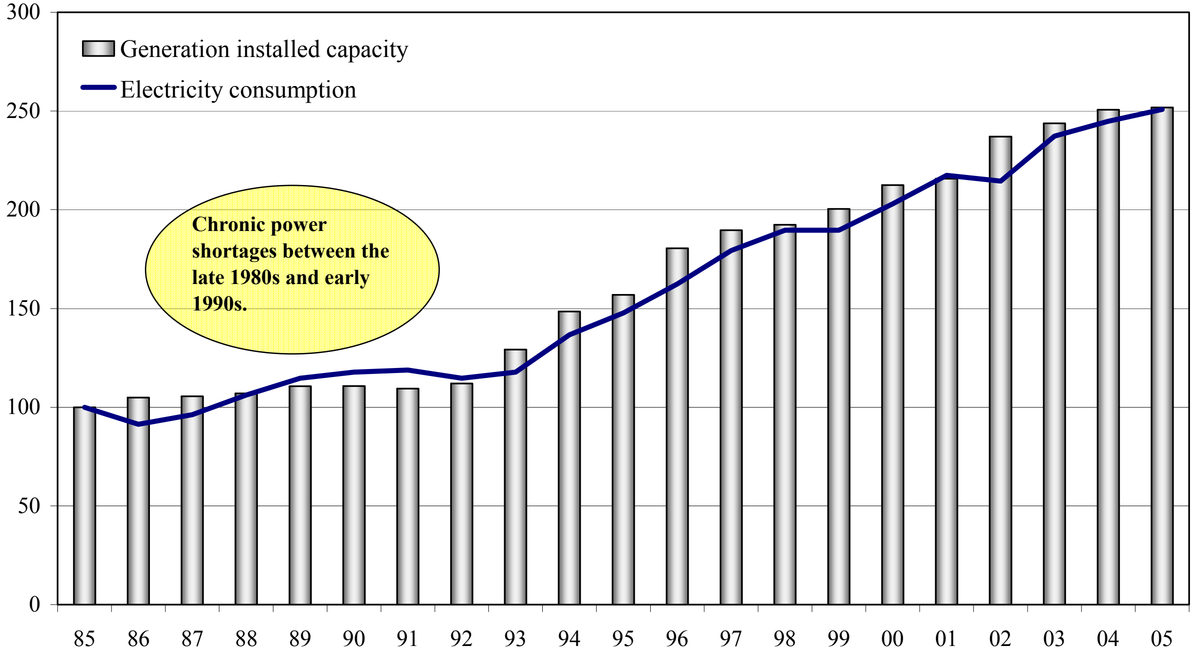
1. Motivation and Contribution
2. Related literature
3. Model, data, and modeling strategy
4. Main findings
5. Policy implications

1. Motivation and contributions

- An adequate, inexpensive, efficient, and reliable electricity supply is critical for sustainable growth and welfare.
- The Philippines faced chronic power shortages in the past, resulting in a significant loss in economic growth.
- Despite the importance of electricity demand forecasting, there have been relatively few empirical studies on electricity demand for developing countries, particularly the Philippines.

The Philippine economy and the power sector

Figure III.1. Generation Installed Capacity and Electricity Consumption (1985=100) 1/



1/ Underlying data: Megawatt for generation installed capacity and kWh for electricity consumption.

Installed capacity	
1986	6,204 MW
2005	15,619 MW

Contributions

- **Cointegration analysis error correction modeling.** There has been very limited formal analysis (such as cointegration analysis) focused on electricity demand in the Philippines covering post-Asian crisis periods.

- **New variables.** Weather and a proxy variable for the stock of electricity using appliances, which were not included in the previous studies on the Philippines.

- **Sector approach.** Electricity consumption in the residential and industrial sector are modeled.

2. Literature review (academic journal)

Studies on electricity demand for advanced countries: e.g.,

- U.S. — Silk and Joutz, 1997, EE; Kamerschen and Porter, 2004, EE
- U.K. — Clements and Madlener, 1999, South Journal of Political Economy
- Australia — Akmal and Stern, 2001 (ANU WP); Narayan and Smyth, 2005, EJ
- New Zealand — Fatai et al., 2003, EJ

Studies on electricity demand for developing countries: e.g.,

- Asian countries — Pesaran et al, 1998, Oxford
- Taiwan — Holtedahl and Joutz, EE
- Mexico — Galindo, 2005, EP
- SE Asia – Hunt and

Research in developing economies is hampered by the quality and historical length for time series analysis.

3.Model, data, and modeling strategy (Residential model)

- Residential electricity demand (Holtedahl and Joutz, 2004)

$$E_t^H = H(I_t, P_t^H, A_t)$$

- Model to estimate

$$eh = c + \beta_1 \times i + \beta_2 \times ph + \beta_3 \times a$$

$$\beta_1 > 0, \beta_2 < 0, \beta_3 > 0.$$

Where *eh* is residential consumption per capita,
i is real income per capita,
ph is the residential price of electricity, and
a is the stock of electric appliances per capita.

3.Model, data, and modeling strategy (Industrial Model)

- Industrial electricity demand is derived from a production function approach

$$Y_t^P = F(K_t^P, E_t^P) \longrightarrow E_t^P = f(Y_t^P, P_t^P)$$

- Model to estimate

$$ep = c + \beta_1 \times gdp + \beta_2 \times pp$$

$$\beta_1 > 0, \beta_2 < 0.$$

Where *ep* is industrial electricity consumption per worker,
gdp is real gross domestic product per worker,
pp is the industrial price of electricity

Key data

- **Estimation period:** 1974-2006 (annual data).
- **Electricity consumption for residential and industrial sectors:** link two data: Philippine Department of Energy for 1985-2006 and Meralco (largest distribution company) for 1974-1985.
- **Electricity prices for residential and industrial sectors:** Meralco's sale prices
- **Proxy for household appliances:** Household furnishing from the Philippines' National Accounts. Stock data are estimated using a perpetual inventory model.
- **Weather conditions:** Cooling degree days - the measurement of the severity and duration of hot weather and calculated as the difference between an average daily temperature and a reference temperature (25˚C).

Figure III.1. Residential Electricity Consumption Per Capita
(In logarithm)

Figure III.1a. With Income Per Capita (i)

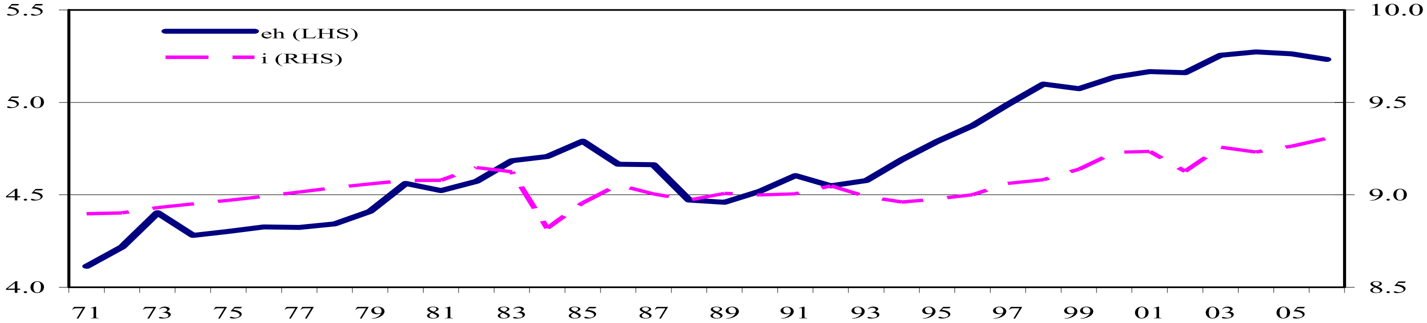


Figure III.1b. With Residential Prices (ph)

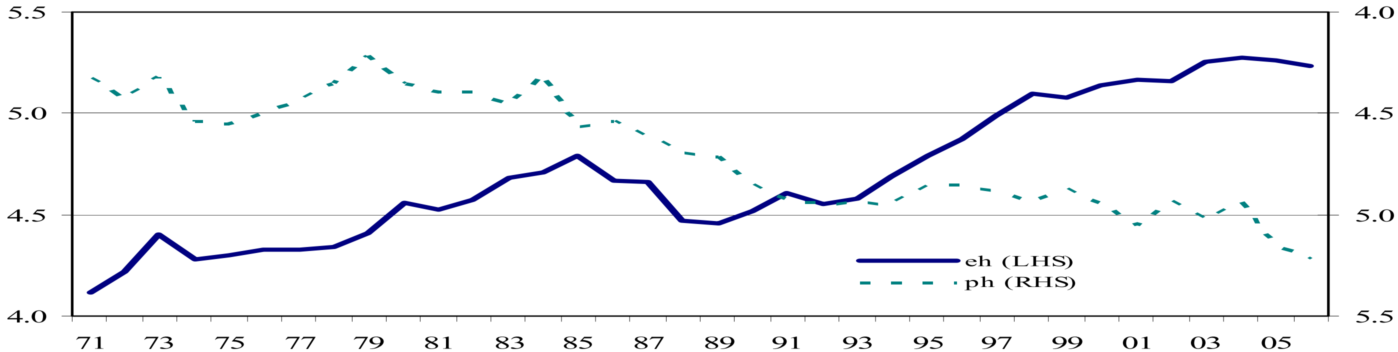


Figure III.1c. With Stock of Electronic Appliances Per Capita (a)

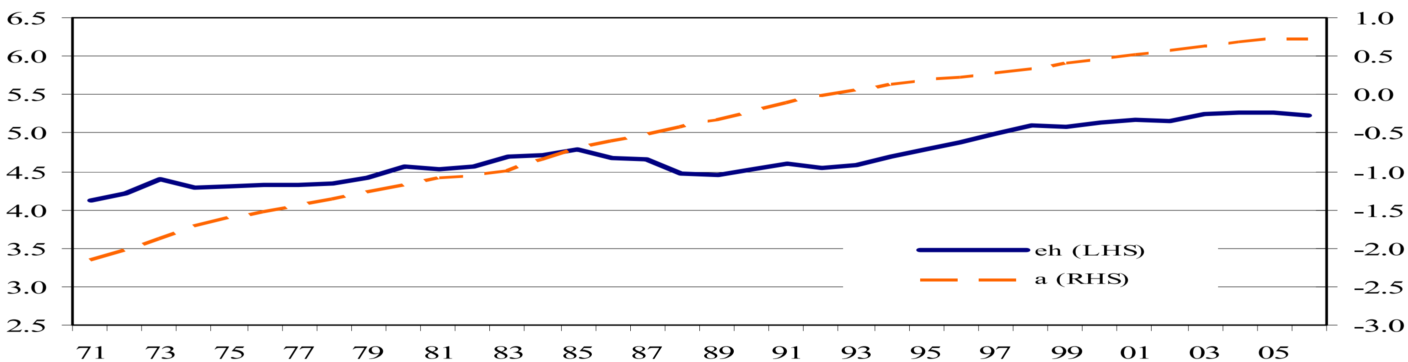


Figure III.2. Industrial Electricity Consumption Per Labor

(In logarithm)

Figure III.2a. With GDP Per Labor (gdp)

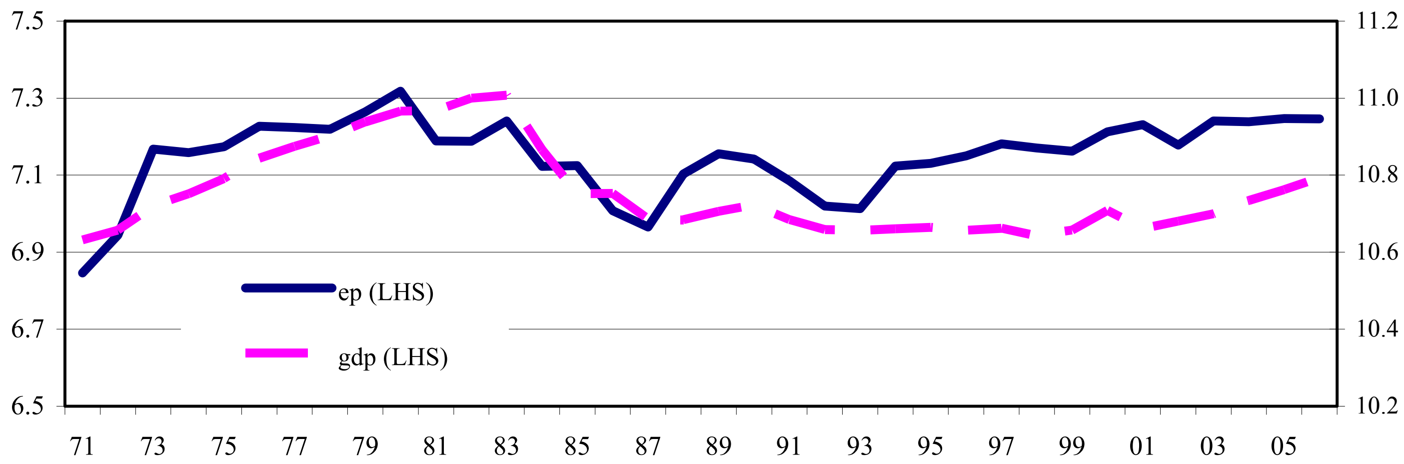
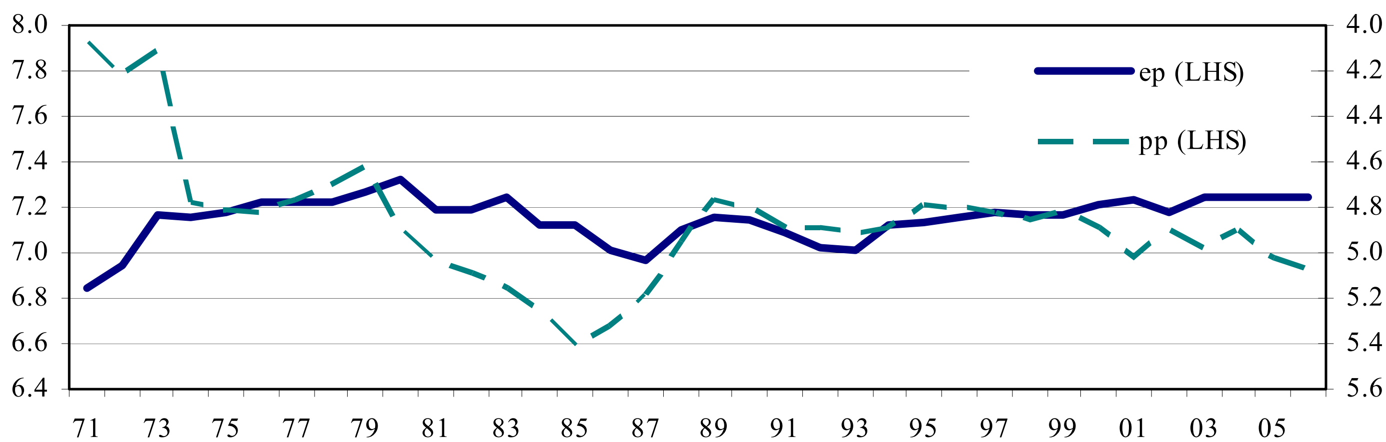


Figure III.2b. With Industrial Prices (pp)



Modeling strategy: Econometric Time Series

- **Focus of our research:** Investigating the behavior of electricity consumption and its interactions with other relevant variables (e.g., i or gdp) in the long-run.

- **Multivariate (VAR) system cointegration approach:** Engel and Granger (1987) and Johansen (1988 and 1991)

  ➔ Key advantages — no assumptions about endogeneity issues required.

- **A general-to-specific approach:** Starting with an explicit stochastic formulation of all relevant data in a system and then reduce the general dynamic model by imposing testable restrictions on the parameters.

- **Vector error correction:** To take account of he short-run dynamics of the variables under consideration.

Modeling strategy (2)

Determinants of Electricity Consumption		
Sector	Long-run	Short-run
Residential (per capita)	○ Real personal disposable income per capita ● Relative residential electricity price with respect to GDP deflator ○ Real stock of electronic appliances per capita	● A change in residential electricity consumption (lags) ○ A change in real personal disposable income per capita (lags) ● A change in real stock of electronic appliances (lags) ○ A change in the relative residential electricity price with respect to GDP deflator
Industrial (per labor)	○ Industrial output per labor ● Relative industrial electricity price with respect to GDP deflator	● A change in residential electricity consumption (lags) ● A change in industrial output per labor (lags) ● Relative industrial electricity price with respect to GDP deflator (lags) ○ Gap of the relative residential electricity price with respect to GDP deflator from its historical average.

1/ ○ indicates those variables selected for final models, while ● indicates those variable initially selected for unrestricted models but later dropped.

Long run model - summary

- Residential electricity consumption model

$$eh = i + \underset{[7.023]^{**}}{0.257} \times a$$

Speed of adjustment coefficients $\begin{cases} d(eh)equation & -0.320[-2.775]^{**} \\ d(i)\ equation & 0.218\,[2.940]^{**} \end{cases}$

- Industrial electricity demand

$$ep = \underset{[2.743]^{**}}{0.299} \times gdp + \underset{[-3.408]^{**}}{0.004} \times t$$

Speed of adjustment coefficients $\begin{cases} d(ep)equation & -0.437[-2.517]^{**} \\ d(gdp)equation & 0.214\,[2.623]^{**} \end{cases}$

ECM-type electricity demand models (Final results based on general-to-specific approach)

Residential sector

$$deh = -\underset{[-1.89]^{*}}{0.17} \times LRR(-1) - \underset{[-2.36]^{**}}{0.27} \times dph(-1) - \underset{[-1.81]^{*}}{0.69}$$

$$di = \underset{[3.82]^{***}}{0.24} \times LRR(-1) - \underset{[-5.75]^{***}}{0.72} \times di(-1) - \underset{[-3.56]^{***}}{0.37} \times di(-2) + \underset{[3.97]^{***}}{1.08} - \underset{[-7.20]^{***}}{0.29} \times debtdummy$$

$$where\ LRR = eh - (i + \underset{[7.023]^{**}}{0.257} \times a)$$

Industrial sector

$$dep = -\underset{[-2.70]^{**}}{0.36} \times LRR(-1) - \underset{[-2.71]^{**}}{0.12} \times ppgap + \underset{[2.71]^{**}}{1.38}$$

$$dgdp = \underset{[2.99]^{**}}{0.19} \times LRR(-1) - \underset{[-2.94]^{***}}{0.71} - \underset{[-8.37]^{***}}{0.13} \times debtdummy$$

$$where\ LRP = ep - (\underset{[2.743]^{**}}{0.299} \times gdp - \underset{[-3.408]^{**}}{0.004} \times t)$$

4. Main findings

- **Long-run income elasticities:** The long run income elasticity of residential electricity demand is **unity**, while that of the stock of electric appliances is **0.25**. For industrial electricity demand, the income elasticity is **0.3**, much lower than that for residential electricity demand.

- **Short-run income elasticities:** The short-run income variables are insignificant, suggesting zero short-run income elasticity.

- **Electricity price:** Electricity prices are the important determinants of short-run electricity demand for both residential and industrial sectors. In the residential electricity demand model, a change in the residential electricity price affects a change in electricity demand, with the short-run price elasticity estimated as -0.27. In the industrial electricity demand model, interestingly, it is the level of the electricity price, rather than the change, that affects demand as a short-run factor.

Main findings (continued)

- **Granger causality:** For both residential and industrial electricity demand functions, there is no evidence that income variables are weakly exogenous. This implies that electricity demand and income (or GDP) cause each other in the Granger sense.

- **Temperature:** In other countries, such as Denmark, U.S., Greece, and Namibia, temperature is an important determinant of electricity demand. However, in the case of the Philippines, this variable appears insignificant. Further research should be conducted on the impact of temperature (cooling demand) and weather.

5. Policy Implications: Forecasting

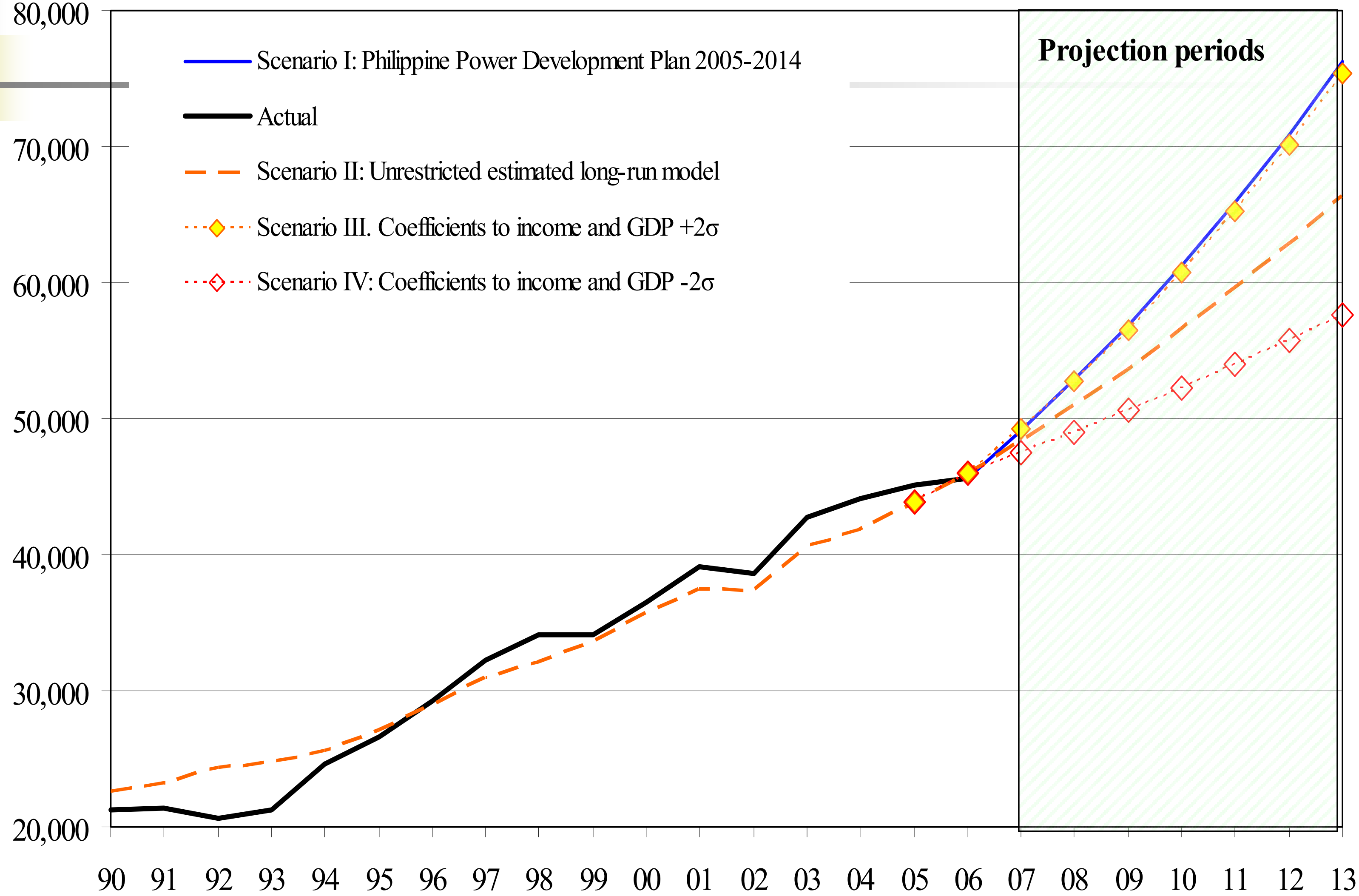
1. Philippines' Department of Energy official forecast for electricity demand in the Power Development Plan (PDP) 2005-2014 was 7.6% annually. The forecast was based on annual real GDP growth of 6.7% and population and labor force growth of 2% each. The implied income elasticity of demand was 1.13.

2. However, the research above suggests that the income elasticity in the Residential sector is lower and closer to unity. Further, the income elasticity in the industrial sector is only 0.3.

3. Using the PDP assumptions and assuming the stock of electricity using appliances increase with GDP, we forecast electricity demand increasing only 5.4% annually.

4. The accompanying figure shows that the PDP prediction lies just above the upper 95% confidence interval.

Figure III.8. Alternative Scenarios
(Total electricity demand; in gWh)



Policy Implications: Electricity Pricing

1. The electricity tariffs is a contentious and sensitive social issue. It has often caused public strife.
2. The potential adverse impact on industry competitiveness from higher tariffs is real.
3. Electricity tariffs for industrial users in the Philippines were among the highest in the ASEAN countries.
4. Higher electricity prices would undermine the Philippines' attractiveness to foreign investors.

Policy Implications: Electricity Pricing (2)

5. Our models suggest this is true, a higher level of the electricity price in the industrial sector would reduce both industrial electricity demand and indirectly GDP.

6. In 2006, the real industrial electricity price was 160 centavos per kWh (in nominal terms, 8 peso, equivalent to US 16 cents), while the average real electricity price for the 1974-2006 periods was 141 centavos. Thus, the 2006 price was 13% higher and would lead to a 1.6 percent reduction in industrial electricity demand in the short-run.

7. This is small. But the larger the price gap, the more elastic or greater a drop in electricity consumption would be.

Thank you.

Supplementary slides

Results of other studies

Country	Period	Dependent variable	Long-run model: Income	Price	Others		Short run model: ΔElectricity	ΔIncome	ΔPrice	Others		Source
Advanced countries												
Australia	1969-2000	Residential electricity	0.32	-0.54	1.69	Temperature	---	n.s.	-0.26	n.s.	ΔTemperature	Narayan et.a. (2005)
					0.16	Gas price				n.s.	ΔGas price	
	1969q3-1998q2	Residential electricity	0.52	-0.95	0.21	Gas price	---	---	---	---		Akmal and Stern (2001)
					0.38	Other fuel price						
Denmark	1948-1990	Total electricity	1.21	-0.47	---		n.s.	0.67	-0.14	0.41	ΔTemperature	Bentzen and Engsted (1992)
New Zealand	1960-1999	Total electricity	0.81	-0.59	0.42	Consumer price index	n.s.	0.24	-0.18	0.25	ΔConsumer price index	Fatai, et.al. (2003)
U.S.	1949-1993	Residential electricity	0.52	-0.48	0.26	Cooling degree days	0.53	0.39	-0.28	0.16	ΔCooling degree days	Silk and Joutz (1997)
					0.16	Heating degree days				-0.04	ΔHeating degree days	
					0.04	Interest rate				-0.01	ΔInterest rate	
					0.06	Oil price				0.11	ΔOil price	

Results of other studies (2)

Country	Period	Dependent variable	Long-run model: Income	Price	Others		Short run model: ΔElectricity	ΔIncome	ΔPrice	Others		Source
Developing countries												
China	1952-2000	Total electricity	1.10	-1.32	---		---	---	---	---		Cheung et.al. (2003)
	1978-2001	Total electricity	0.78	-0.02	0.57	Population	0.09	0.76	0.02	-0.18	ΔPopulation	
					0.53	Heavy industry share in GDP				-0.48	ΔHeavy industry share in GDP	
					0.33	Electricity consumption efficiency				-0.83	ΔElectricity consumption efficiency	
Greece	1986m1-1999m12	Residential electricity	1.56	-0.41	-0.19	Temperature	0.24	0.20	---	---		Hondroyiannis (2004)
Israel	1973q1-1994q4	Residential electricity	---	-0.58	1.09	Private consumption	---	---	---	---		Beenstock et.al. (1997)
		Industrial electricity	0.99	-0.44	---		---	---	---	---		Beenstock et.al. (1997)
Namibia	1980q1-	Total electricity	0.59	-0.30	-0.36	Temperature	---	---	---	---		De Vita, et.
Taiwan	1957-1995	Residential electricity	1.04	-0.16	-0.16	Oil price	---	0.23	-0.15	1.61	ΔUrbanization rate	Holtedahl and Joutz (2004)
					3.91	Urbanization rate				0.03	Temperature	
Turkey	1968-2005	Residential electricity	0.70	-0.52	0.04	Urbanization rate	---	n.s.	-0.10	0.04	ΔUrbanization rate	Halicioglu (2006)

4. Estimation results
Long run model - residential sector (unrestricted)

Endogenous variables	Residential electricity consumption (eh, i, ph, a)		Residential electricity consumption (eh, i, a)	
Lag order in the original VAR model	2	3	2	3
Model number	I	II	III	IV
Normalized β cointegrating vector				
eh	1.000	1.000	1.000	1.000
	...	...	...	...
i	-1.076	-0.931	-1.179	-0.933
	-3.085 ***	*-2.444* *	*-3.732* ***	*-2.743* **
ph	-0.292	-0.200	...	...
	-1.239	*-0.800*	...	...
a	-0.124	-0.191	-0.219	-0.249
	-1.580	*-2.096* *	*-6.426* ***	*-6.480* ***
Speed of adjustment (α) parameters				
d(eh) equation	-0.141	-0.265	-0.186	-0.299
	-1.560	*-2.551* *	*-1.774* *	*-2.597* *
d(di) equation	0.270	0.210	0.291	0.215
	4.104 ***	*3.164* ***	*3.910* ***	*2.909* **
d(a) equation	-0.049	-0.027	-0.056	-0.028
	-2.019 **	*-0.902*	*-1.985* **	*-0.907*
Trace tests				
r=0	47.371	42.815	35.671	35.879
	[0.055] *	[0.137]	[0.009] ***	[0.009] ***
r≤1	17.056	15.867	6.886	10.339
	[0.636]	[0.721]	[0.591]	[0.255]

Long run model - Residential sector (restricted)

Endogenous variables	Residential electricity consumption (eh, i, a)					
Lag order in the original VAR model	2	3	2	3	2	3
Model number	III	IV	III	IV	III	IV
LR test for parameter restrictions test	*a* is weakly exogenous		*a* is weakly exogenous, and coefficint to i =1		*a* is weakly exogenous, coefficint to i =1, and *i* is weakly exogenous,	
Chi square	4.106	0.921	4.955	0.955	14.944	10.183
	[0.043] **	[0.337]	[0.084]	[0.620]	[0.001] ***	[0.017] **
Normalized β cointegrating vector						
eh	1.000	1.000	1.000	1.000	1.000	1.000
i	-1.313	-1.065	-1.000	-1.000	-1.000	-1.000
	-4.083 **	*-3.191* **				
a	-0.233	-0.257	-0.238	-0.257	-0.231	-0.222
	-6.705 **	*-6.818* **	*-6.895* **	*-7.023* **	*-5.343* **	*-4.854* **
Speed of adjustment (α) parameters						
d(eh) equation	-0.248	-0.317	-0.268	-0.320	-0.401	-0.435
	-2.373 *	*-2.700* **	*-2.701* *	*-2.775* **	*-4.501* ***	*-4.362* ***
d(di) equation	0.271	0.224	0.244	0.218	0.000	0.000
	3.674 **	*3.009* **	*3.308* **	*2.940* **	...	...
d(a) equation	0.000	0.000	0.000	0.000	0.000	0.000
	...	...	...	...	...	...

Long run model - industrial sector (unrestricted)

	Industrial electricity consumption
Endogenous variables	(ep, gdp)
Lag order in the original VAR model	2
Model number	V
Normalized β cointegrating vector	
ep	1.000
	...
gdp	-0.299
	-2.435 **
time trend	-0.004
	-3.408 **
Speed of adjustment (α) parameters	
d(ep) equation	-0.437
	-2.517 **
d(gdp) equation	0.214
	2.623 **
Trace tests	
r=0	29.764
	[0.016] *
r≤1	0.521
	[1.000]

Long run model - industrial sector (unrestricted)

	Industrial electricity consumption
Endogenous variables	(ep, gdp)
Lag order in the original VAR model	2
Model number	V
LR test for parameter restrictions test	*gdp* is weakly exogenous
Chi square	7.158
	[0.007]
Normalized β cointegrating vector	
eh	1.000
gdp	-0.266
	-1.932 *
time trend	-0.004
	-2.773 *
Speed of adjustment (α) parameters	
d(ep) equation	-0.725
	-5.593 **
d(gdp) equation	0.000
	...

Full electricity demand model including short-run factors Residential sector (general model)

$$deh = -\underset{[-2.44]^{**}}{0.29} \times LRR(-1) - \underset{[-0.28]}{0.05} \times deh(-1) + \underset{[0.99]}{0.19} \times deh(-2) - \underset{[-0.08]}{0.02} \times di(-1) - \underset{[-1.08]}{0.21} \times di(-2)$$

$$- \underset{[-0.43]}{0.32} \times da(-1) - \underset{[-0.68]}{0.63} \times da(-2) - \underset{[-2.08]^{*}}{0.31} \times dph(-1) - \underset{[-0.26]}{0.05} \times dph(-2) + \underset{[0.03]}{0.19} + \underset{[0.56]}{0.04} \times debtdummy$$

$$- \underset{[-0.14]}{0.01} \times temp$$

$$di = \underset{[3.12]^{**}}{0.24} \times LRR(-1) - \underset{[-1.44]}{0.18} \times deh(-1) + \underset{[0.15]}{0.02} \times deh(-2) - \underset{[-2.67]^{**}}{0.46} \times di(-1) - \underset{[-3.41]^{***}}{0.43} \times di(-2)$$

$$+ \underset{[1.50]}{0.71} \times da(-1) - \underset{[-1.41]}{0.85} \times da(-2) - \underset{[-1.52]}{0.15} \times dph(-1) + \underset{[0.68]}{0.08} \times dph(-2) + \underset{[0.56]}{0.23} - \underset{[-6.44]^{***}}{0.28} \times debtdummy$$

$$- \underset{[-0.46]}{0.03} \times temp$$

Where LRR is long-run cointegration relationship (the error correction term) lagged one period

Full electricity demand model including short-run factors Industrial sector (general model)

$$dep = -\underset{[-2.37]^{**}}{0.43} \times LRP(-1) - \underset{[-0.54]}{0.09} \times dep(-1) + \underset{[0.99]}{0.30} \times dgdp(-1) - \underset{[-1.21]}{0.11} \times ppgap - \underset{[-0.47]}{0.03} \times pp(-1)$$

$$+\underset{[2.37]}{1.68} + \underset{[0.17]}{0.01} \times debtdummy + \underset{[0.44]}{0.02} \times temp$$

$$dgdp = \underset{[2.17]^{**}}{0.19} \times LRP(-1) - \underset{[-0.57]}{0.05} \times dep(-1) - \underset{[-0.91]}{0.13} \times dgdp(-1) - \underset{[-1.14]}{0.05} \times ppgap - \underset{[-0.26]}{0.09} \times pp(-1)$$

$$-\underset{[-2.15]}{0.73} - \underset{[-5.22]^{***}}{0.13} \times debtdummy - \underset{[-0.52]}{0.01} \times temp$$

Where LRR is long-run cointegration relationship (the error correction term) lagged one period

Figure III.1. Residential Electricity Consumption Per Capita

(In logarithm)

Figure III.1a. With Income Per Capita (i)

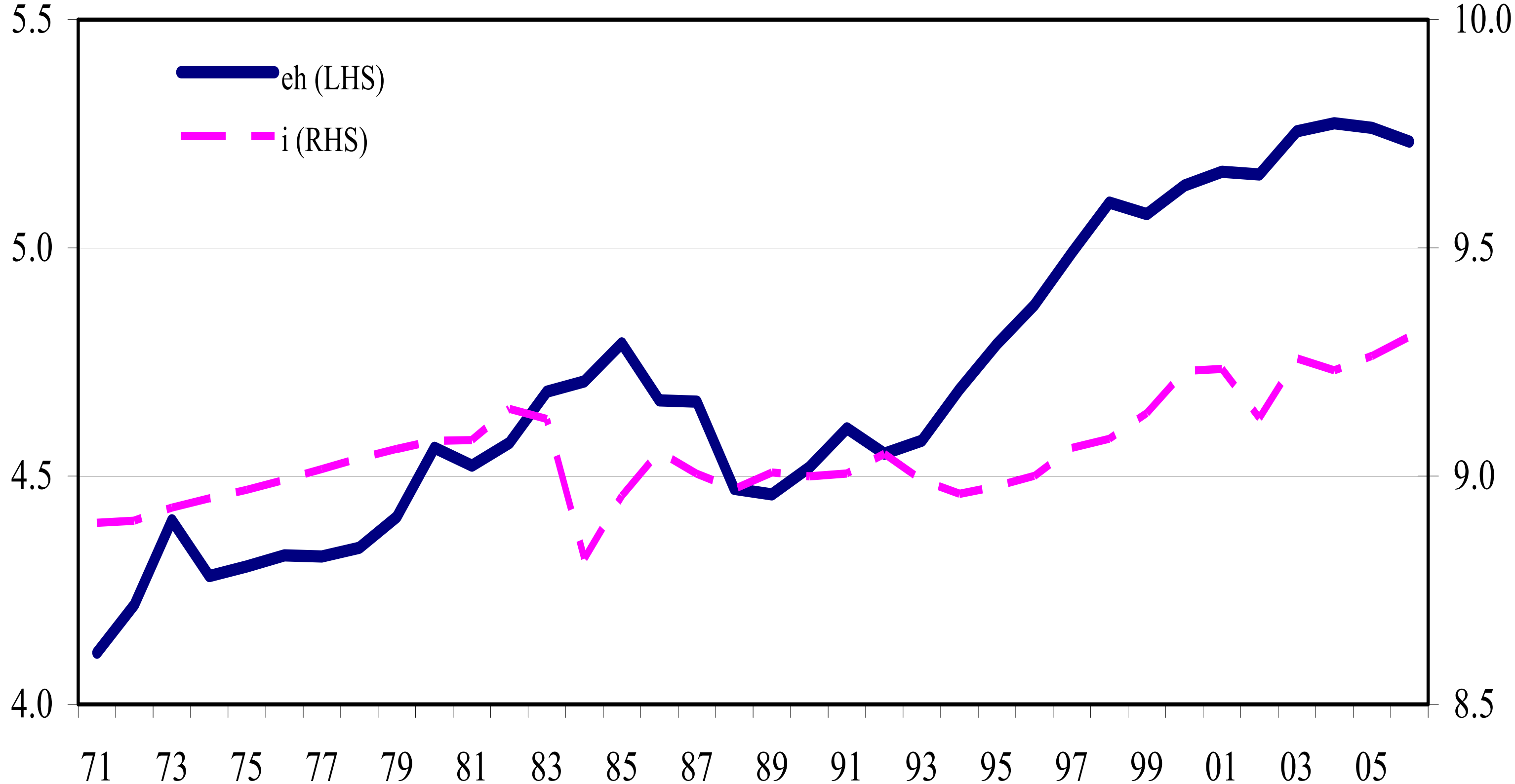


Figure III.1b. With Residential Prices (ph)

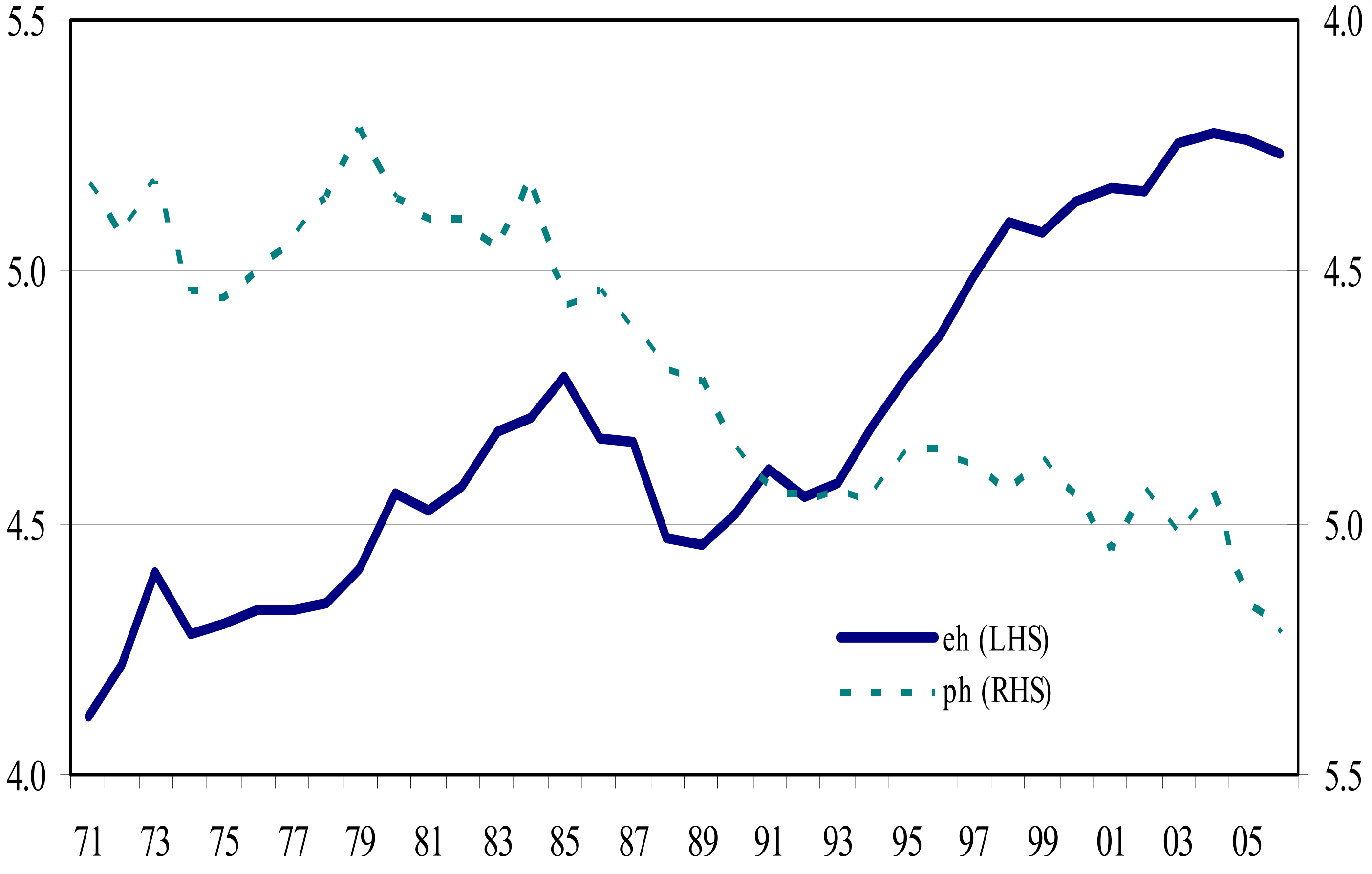


Figure III.1c. With Stock of Electronic Appliances Per Capita (a)

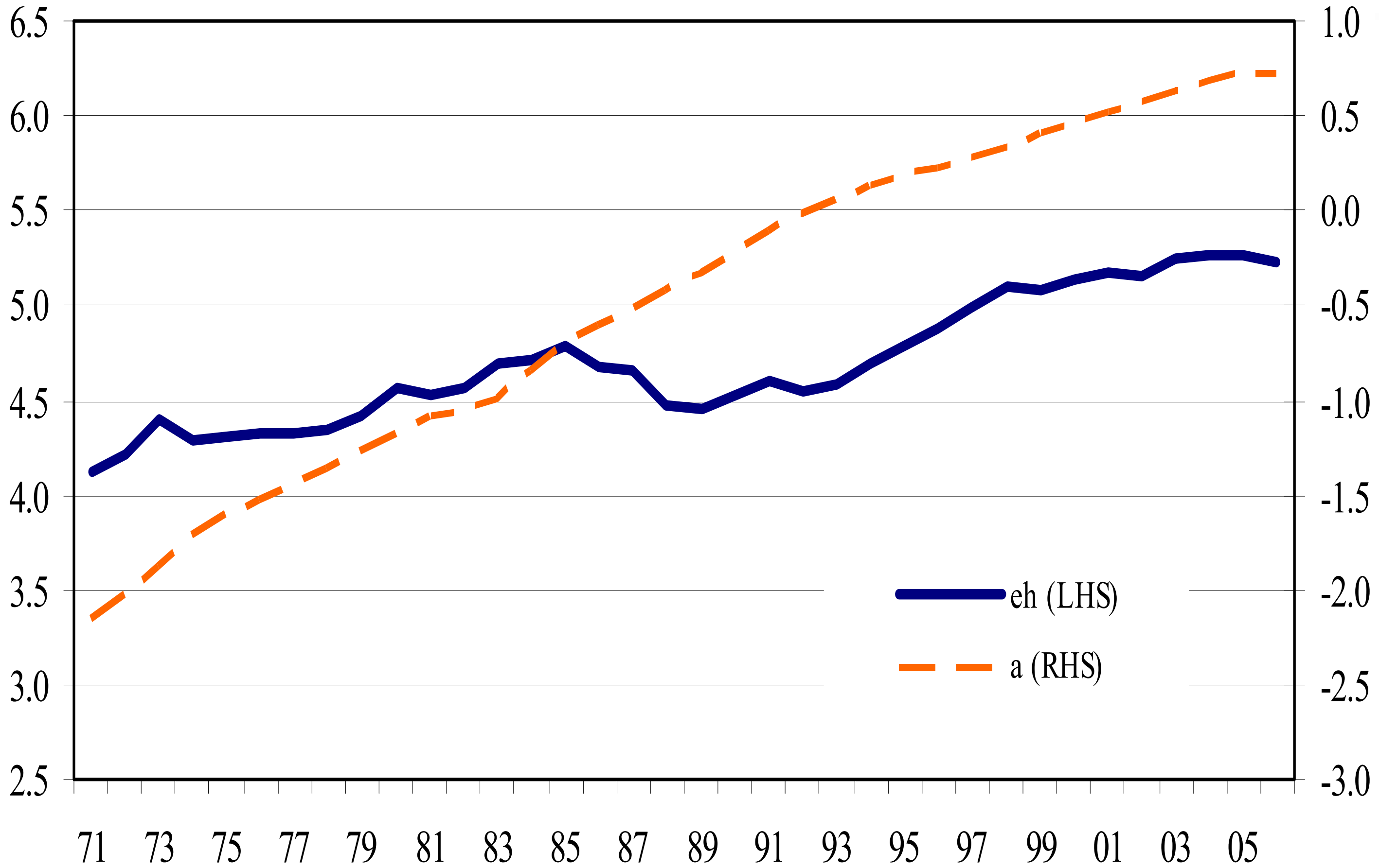


Figure III.2. Industrial Electricity Consumption Per Labor

(In logarithm)

Figure III.2a. With GDP Per Labor (gdp)

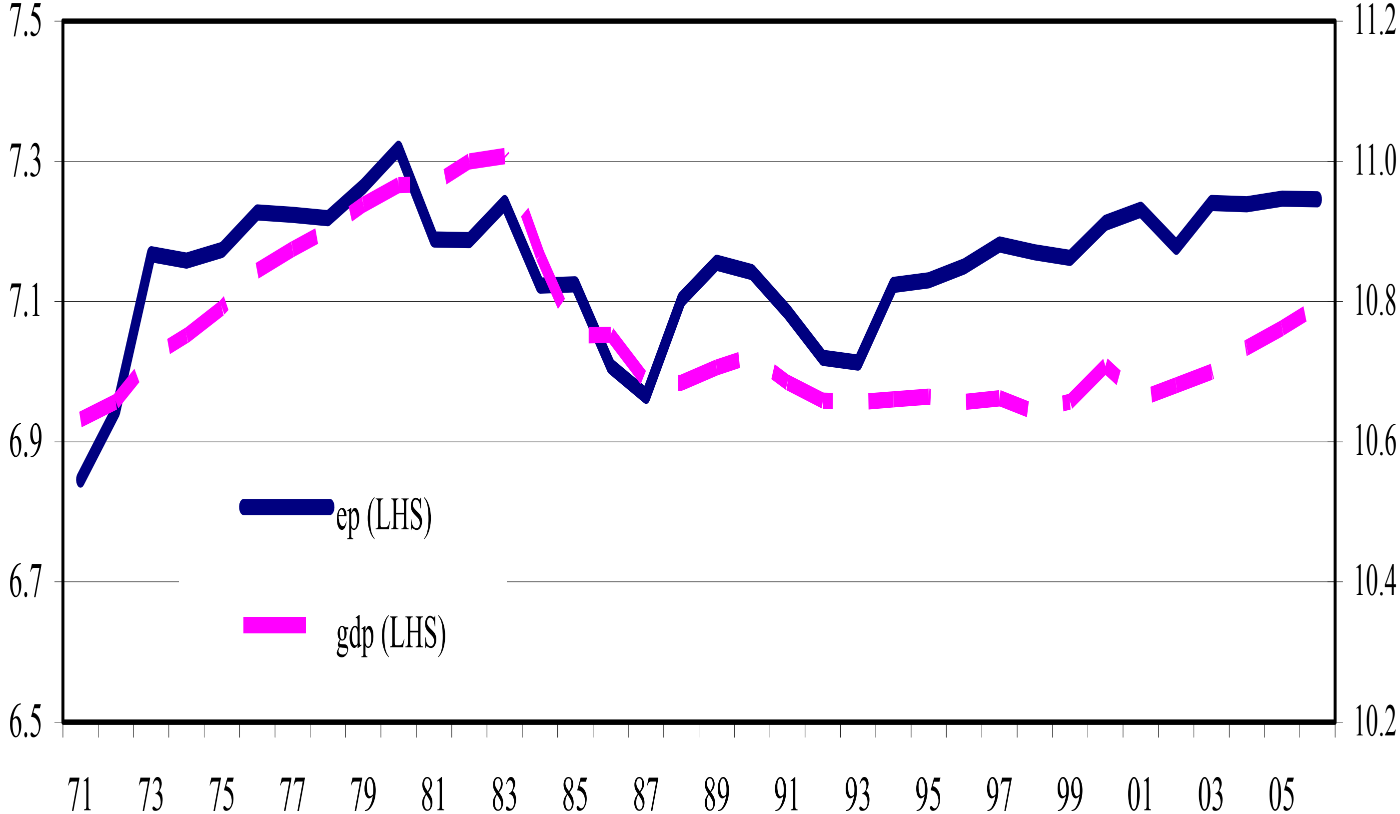


Figure III.2b. With Industrial Prices (pp)