The Light at the End of the Tunnel

The Impact of Policy on the Global Diffusion of Fluorescent Lamps

Presented by Suchita Srinivasan

Ph.D Candidate in International Economics, The Graduate Institute (Geneva, Switzerland)

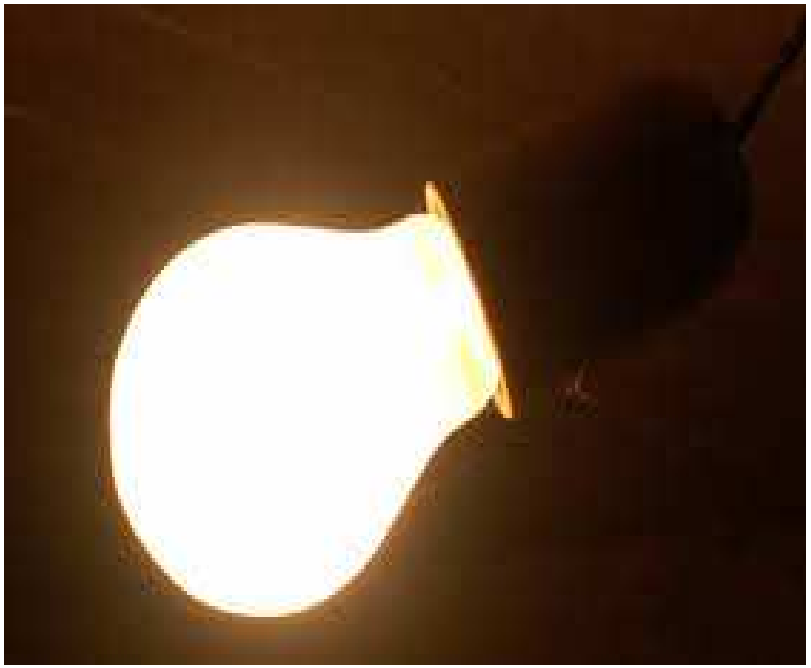
Agenda

- Introduction
- Objective
- Empirical Model and Results
- Policy Implications
- Conclusion

Introduction-I

- Light production accounts for about 19% of global electricity use p.a, and 70% of the CO_2 emissions of all the world's passenger vehicles (IEA, 2005)

- Main types of lamps compared in the paper:
  - Incandescent lamps- inefficient (90% of electrical energy wasted as heat)
  - Fluorescent lamps (FL, includes CFL)-higher initial price, but lower operating costs than incandescents



Introduction-II

	Incandescent Lamp	CFL
Life-Span (hours)	1000	10000
Efficacy (lm/W)	12	60
Lamp power(W)	75	15
Light Output	900	900
Initial Cost of Bulb (USD)	0.50	10
Efficiency	5% of the energy consumed converted to light	25% of the energy consumed converted to light

Source: IEA: Light's Labour Lost: Policies for Energy Efficient Lighting (2006)

- Largest barrier to the adoption of CFL is the high initial cost
- Other barriers:
  - Incomplete or inaccurate consumer awareness
  - Uncertainty about qualities of the lamp such as lifetime, efficiency, etc.
  - Design limitations: bulkier, require different light fittings, limited colour ranges, only available in higher cooler-light values (initially)

Introduction-III

Type of policy (focus on the residential sector)	Example
Ban on Incandescent Bulbs	Cuba: Banned the import of incandescent lamps since April 2005. Incandescent lamp replacement program starting in August 2005 & replaced all 9.4 million incandescent lamps with CFL
Minimum Energy Performance Standards (MEPS)	Brazil: CFL bulbs with power between 15 and 25 W should have a minimum luminous efficacy of 60 lm/W
Mandatory Labelling	Costa Rica: Since 1996, labels displaying the energy consumption and the MEPS mandatory
Voluntary Labelling	Thailand: Since 2002, CFLs with a life of more than 8000 hours may be labelled based on performance and energy data
Awareness Raising and Promotional Campaigns	Ghana: 'Lighting Africa' campaign, which carries out road shows, door-to-door consumer engagement, retailer education drives, etc.
Free CFL Distribution Schemes	Rwanda: First efficient light distribution CDM project in Africa: 50000 lamps distributed for free, then 150000 distributed at subsidised price of 0.30 USD
Subsidies, tax incentives, rebates	Egypt: UNDP/GEF Project involving the Ministry of Electricity and Energy, which will distribute 3-4 million CFL, at a 50% subsidy to low-income families
	Ghana eliminated tariffs and VAT on CFLs, Tunisia introduced a progressive consumption tax (from 10% in 2007 to 50% in 2011) on the sale of incandescent lamps

Objective

- To explain the role of:
  - Domestic policies
  - Trade policy
  - Nature of governance

  in the diffusion of compact fluorescent lamps into a sample of low and middle-income countries

- Questions:
  - How important, relatively, are the different policies for this sample of countries?
  - Should some policies be prioritized over others, at least in the beginning?
  - How important are factors such as instruments of trade policy and nature of governance in influencing technology diffusion?

Data Sources

	Variable	Data Source	Notes
Dependent variable	Share of value of net CFL imports	UN COMTRADE	Defined as the value of net imports of CFL as a proportion of net imports of CFL and net imports of incandescent lamps
Regulation	Incandescent Ban	UNEP en.lighten Country Lighting Assessments/ other country-level reports	Dummies which are manually coded (take the value 1 when the policy is in place) using the UNEP en.lighten Global Policy Map
	MEPS		
Information	Mandatory and Voluntary Labels		
	Awareness Programs		
Price Incentives	Free CFL Distribution		
	Subsidies		
	Ratio of Tariffs on CFL to Tariffs on IB	WITS (TRAINS) Tariff Data	
	Trade to GDP	World Bank Database	
	Trade Agreement Indicator	De Sousa, J.(2012) , " The currency union effect on trade is decreasing over time", Economic Letters, 117(3), 917-920	Dummy which takes the value 1 if the county is in a trade agreement with one of the top 5 CFL exporters in a given year
	Distance times the share of CFL exports of the 5 largest exporters	Centre d'Etudes Prospectives et d'Informations Internationales (CEPII) Database; UN COMTRADE	
	Polity Index	Polity IV Dataset	Varies from -10 to 10: -10 for a strict autocracy, 10 for a strict democracy
	Sum of Lights	National Oceanic and Atmospheric Administration (NOAA) National Climatic Data Center Data (Satellite Data)	Sum of night-time lights (measure of development of the country)
	GDP Per Capita	World Bank Database	

Countries in the Data Sample (1993-2013)

Albania	Costa Rica	Guatemala	Madagascar	Pakistan	Suriname
Argentina	Cote d'Ivoire	Guinea-Bissau	Malawi	Panama	Swaziland
Bangladesh	Cuba	Guyana	Malaysia	Peru	Tajikistan
Belarus	Democratic Republic of Congo (Zaire)	Haiti	Mali	Philippines	Timor-Leste
Belize	Dominica	Honduras	Mauritius	Romania	Togo
Benin	Dominican Republic	India	Mexico	Rwanda	Tunisia
Bolivia	Egypt	Iran	Morocco	Saint Lucia	Turkey
Brazil	El Salvador	Jamaica	Mozambique	Senegal	Uganda
Bulgaria	Ecuador	Jordan	Namibia	Seychelles	Ukraine
Cape Verde	Ethiopia	Kazakhastan	Nepal	South Africa	Venezuela
Central African Republic	Gambia	Kenya	Nicaragua	Sri Lanka	Vietnam
Colombia	Ghana	Lebanon	Nigeria	Sudan	Zambia
Zimbabwe					

Methodology-I

- Panel data estimation using region-by-year fixed effects (and panel-corrected standard errors)
- Estimation 1: $NM_{ijt} = D_{it} + T_{it} + G_{it} + D_{it} * G_{it} + X_{it} + \alpha_{jt}$, where

NM_{ijt} denotes net imports of country i (belonging to region j) in year t

i denotes country

j denotes region

t denotes year

D_{it} refers to a set of country-year specific policy dummies

T_{it} refers to a set of country-year specific trade policy variables

G_{it} refers to a set of country-year specific governance variables

X_{it} refer to a set of country-year specific controls

α_{jt} denotes region-by-year fixed effects

Ratio of Net imports of CFL to Sum of Net imports of CFL and Net Imports of IB	1	2	3	4	5
REGULATION	-6.24 (16.61)	-6.41 (31.56)	-5.33 (5.88)	-4.54 (16.18)	
INFORMATION	36.39*** (19.54)	29.70* (18.36)	29.34 (25.83)	31.48* (18.30)	33.96* (19.90)
PRICE INCENTIVES	42.25** (16.65)	39.33*** (15.12)	36.60*** (14.78)	22.9 (20.32)	44.14*** (16.05)
RATIO OF TARIFFS ON CFL TO INCANDESCENT BULBS	-28.78*** (11.04)	-33.23*** (11.16)	-29.25*** (10.88)	-29.46*** (10.23)	-30.43*** (11.55)
GDP PER CAPITA	-0.02** (0.01)	-0.02*** (0.01)	-0.02*** (0.01)	-0.02** (0.01)	-0.02** (0.01)
TRADE AGREEMENT INDICATOR	44.93* (26.90)	52.60** (27.44)	49.98** (25.05)	47.98** (24.25)	48.01 (30.06)
DISTANCE TIMES THE SHARE OF CFL EXPORTS OF TOP 5 EXPORTERS	-0.01 (0.01)	-0.01 (0.01)	-0.01 (0.01)	-0.01 (0.01)	-0.01 (0.01)
TRADE TO GDP RATIO (TRADE OPENNESS)	-0.87** (0.38)	-0.86 (0.42)	-0.79** (0.38)	-0.72** (0.35)	-0.91** (0.45)
SUM OF LIGHTS (MEASURE OF ACCESS TO ELECTRICITY)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
POLITY INDEX	1.99 (2.16)	2.25 (2.38)	1.71 (2.17)	0.63 (2.27)	2.78 (2.30)
REGULATION INTERACTED WITH POLITY INDEX		-0.31 (4.33)			
INFORMATION INTERACTED WITH POLITY INDEX			0.22 (3.67)		
PRICE INCENTIVES INTERACTED WITH POLITY INDEX				3.71 (2.71)	
MEPS					-2.46 (38.3)
INCANDESCENT BAN					-2.67 (26.40)
MEPS INTERACTED WITH POLITY INDEX					-0.76 (5.07)
INCANDESCENT BAN INTERACTED WITH POLITY INDEX					-0.27 (3)
NUMBER OF OBSERVATIONS	519	519	519	519	519
REGION-BY-YEAR FIXED EFFECTS	Yes	Yes	Yes	Yes	Yes
WALD CHI2	164.47	180.16	179.47	621.26	174.48
(PROB > CHI2)	0.0003	0	0	0	0

Note: Standard errors in red below the coefficients, '*', '**', '***' denote significance at the 10%, 5% and 1% levels respectively. Results don't change significantly on including a time trend.

Methodology-II

- Estimation 2: To account for endogeneity: system Generalised Method of Moments (GMM), using Arellano-Bover (1998) method of estimation for dynamic panels

$$NM_{it} = x_{it}\beta_1 + w_{it}\beta_2 + u_{it} \text{ for } i = 1, ..., N; t = 1, ..., T, where$$

$$u_{it} = v_i + e_{it}$$

NM_{it} denotes the share of net imports of CFL in country i in year t

v_i denote the county fixed effects

x_{it} denote the strictly exogenous covariates

w_{it} denote the possibly endogenous covariates (and NM_{it-1})

μ_{it} denotes the stochastic error term

Ratio of Net imports of CFL to Sum of Net imports of CFL and Net Imports of IB	1	2	3	4	5
LAG OF RATIO OF NET IMPORTS OF CFL	0.15*** (0.03)	0.16*** (0.04)	0.16*** (0.04)	0.16*** (0.04)	0.16*** (0.04)
REGULATION	35.43 (32.72)	50.30* (28.48)	40.8 (31.60)	38.62 (33.51)	
INFORMATION	34.12** (17.33)	32.80** (15.80)	29.68* (17.46)	28.29* (16.03)	28.86** (14.44)
PRICE INCENTIVES	43.67** (17.80)	37.71** (18.61)	39.30** (17.49)	25.19* (13.55)	39.15** (19.47)
RATIO OF TARIFF ON CFL TO TARIFF ON INCANDESCENT BULBS	-12.32 (12.56)	-11.37 (12.58)	-9.46 (11.15)	-7.25 (11.43)	-9.44 (11.57)
GDP PER CAPITA	-0.01 (0.01)	-0.01 (0.01)	-0.01 (0.01)	-0.01 (0.01)	-0.01 (0.01)
TRADE AGREEMENT INDICATOR	39.95 (33.16)	43.40 (31.08)	39.94 (32.23)	35.68 (31.58)	39.13 (28.73)
DISTANCE TIMES THE SHARE OF CFL EXPORTS OF TOP 5 EXPORTERS	-0.01 (0.01)	-0.01 (0.01)	-0.01 (0.01)	-0.01 (0.01)	-0.01 (0.01)
TRADE TO GDP RATIO (TRADE OPENNESS)	0.06 (0.13)	-0.01 (0.10)	0.03 (0.12)	0.05 (0.12)	0.00 (0.10)
POLITY INDEX	2.80* (1.66)	2.80** (1.42)	2.41 (1.58)	1.24 (1.25)	2.61* (1.41)
REGULATION INTERACTED WITH POLITY INDEX		-2.28 (3.07)			
INFORMATION INTERACTED WITH POLITY INDEX			-0.05 (2.14)		
PRICE INCENTIVES INTERACTED WITH POLITY INDEX				2.17 (1.58)	
MEPS					45.06 (28.09)
INCANDESCENT BAN					8.67 (14.66)
MEPS INTERACTED WITH POLITY INDEX					-1.03 (4.46)
INCANDESCENT BAN INTERACTED WITH POLITY INDEX					-4.67 (5.90)
NUMBER OF OBSERVATIONS	486	486	486	486	486
YEAR FIXED EFFECTS	Yes	Yes	Yes	Yes	Yes
F-STATISTIC	100.54	108.5	105.44	107.02	103.01
(PROB > F)	0	0	0	0	0
SARGAN TEST	0.984	0.991	0.992	0.992	0.992

Caveats

- There may be differences in consumer behavior between announcement and implementation of policies
- Use of dummies for policies doesn't account for scale of policies, distributional impacts of policies, etc.
- Model proxies diffusion with net imports
- Analysis doesn't factor for differences in operating costs between both types of lamps

Policy Implications- I

- Importance of informational campaigns and subsidies is paramount
  - Biggest barrier to adoption of a new technology is lack of information: policy-makers need to prioritize information provision

  - Results from theoretical model:
    - Once consumers are informed, either subsidies are needed till the price of CFL exceeds that of incandescent lamps or policy-maker needs to ban incandescent lamps
      - Subsidies are a possible short-run solution. In the long run, performance standards can play a role in facilitating domestic production (and thus possibly reducing the price of CFL) and in improving product quality
      - Banning incandescent lamps may leave consumers worse off

Policy Implications- II

- Positive role for trade policy can in encouraging the diffusion of clean technologies
  - Trade agreements with the top exporters can facilitate technology transfer.
  - Low tariffs on technologies primarily transferred through the trade channel also effective

- Importance of governance regime in encouraging clean technology adoption is not clear
  - Empirical results do not suggest that nature of governance affects the implementation of policies

Policy Implications- III

- Governments need to make coordinated efforts to ensure that quality-control standards are maintained by firms
  - For example, countries can coordinate in setting performance standards to ensure that manufacturers follow quality-control guidelines.

- Many countries have resorted to domestic production as a means of mitigating the uncertainty that arises from the imports of low-quality CFL (examples include Poland and Hungary).
  - This offers another channel through which the government can influence CFL adoption: providing incentives to domestic firms to produce these lamps.

Conclusion

- Information and subsidies incentivize consumers to switch to using cleaner technologies
- Regulatory measures such as performance standards and banning incandescent lamps may also be effective in the long-run
- Trade policy matters- tariff and participation in trade agreements work in expected ways
- Nature of government may matter, but the channel is not clear
- Possible extensions:
  - Role of 'policy leader' in influencing adoption in other countries (for example, Cuba in 2005)
  - Importance of product quality
  - Are there differences between autocracies and democracies in the type of policies they use?

Thank You For Your Attention.

Appendix

Literature Review

- Role of policies in explaining the adoption of clean lighting (evidence from country-level studies):
  - **Germany: Demographic characteristics** (Mills and Schleich (2008, 2013)
  - **India: Informational campaigns** (Kumar et. Al (2003))
  - **US: Information, subsidies and standards** (Alcott and Taubinsky (2013))

- Technology Diffusion:
  - **Trade as a channel of technology diffusion**(Coe , Helpman and Hoffmaister (1995), Eaton and Kortum(2002), Keller (2004))
  - **Use of imports as a proxy for technology adoption (**Caselli and Coleman II (2001) and Papageorgiou et. al. (2006))

- Effect of domestic policies, trade policy, and governance (regimes and government effectiveness) on innovation and diffusion :
  - **Effect of domestic policies on innovation** (Johnstone et al (2008))
  - **Effect of domestic policies on diffusion** (Bosetti and Verdolini (2013))
  - **Effect of trade policy on technology adoption** (Reppelin-Hill(1999) , Comin, Dmitriev and Rossi-Hansberg (2013))
  - **Effect of governance on international trade** (Aidt and Gassebner (2010), Levchenko (2007), Mansfield et. al. (2000))

Theoretical Framework

- Two-stage game: policy-makers choose policies in the first stage, consumers choose type of lamp to buy in second stage
- Let A denote CFL, B denote incandescent lamps
- Utility that a consumer derives from a lamp is modeled in the Lancasterian preference framework ((Lancaster (1966, 1971))
- Assume that the only attribute that the consumer cares about is the life of the lamp
- Following Lucas (1975), the total lamp life for the consumer buying A CFL and B incandescent lamps can be expressed as:

$$a_X(A,B) = AV_{AX} + BV_{BX}$$

- Utility maximisation framework (Roberts and Urban (1988)):

$$U(\widetilde{a_X}) = \exp(-r.a_X(A,B))$$

- Assuming $\widetilde{ax}$ follows a normal distribution with mean = $A\overline{V_{AX}} + BV_{BX}$ and variance σ^2_A,

$$E(U(\widetilde{a_X})) = \exp\left[-r\left(A\overline{V_{AX}} + BV_{BX} - \frac{r}{2}\sigma_A^2\right)\right]$$

- Assumptions:

$$E'_j(U(\widetilde{a_X})) > 0$$

$$E''_j(U(\widetilde{a_X})) < 0 \text{ for } j = A \text{ and } B$$

Representative Consumer's Problem (Second-Stage)

$$Max_{A,B}\ E(U(\widetilde{a_X})) = \exp\left[-r\left(A\overline{V_{AX}} + BV_{BX} - \frac{r}{2}\sigma_A^2\right)\right] \text{ subject to}$$

$$(P_A - \tau)A + P_B B = M_L$$

- Representative consumer only chooses one type of lamp (A or B): for him to choose A over B,

$$\frac{MU_A}{P_A - \tau} > \frac{MU_B}{P_B}$$

- This condition can be re-written as:

$$\frac{\overline{V_{AX}} - (rAVar(V_{AX}))}{V_{BX}} > \frac{P_A - \tau}{P_B}$$

- This implies that

$$A = \frac{M_L}{P_A - \tau}$$

$$B = 0$$

Role of Policy-maker (First Stage)

- The choices of the government are the subsidy τ, and the following parameters (R and θ) where R and θ are given by:

$$\overline{V_{AX}} = \gamma R \qquad 0<\gamma<1$$

$$\begin{aligned} \sigma_A^2 &= Var(AV_{AX} + BV_{BX}) \\ &= A^2 Var(V_{AX}) \text{ (since } V_{BX} \text{ is known and constant)} \\ &= A^2(\alpha - \beta\theta) \quad \alpha,\beta > 0 \end{aligned}$$

- θ represents the government's 'effectiveness' in providing information to consumers

$$\begin{aligned} \theta &= \theta(g), \\ &= (L) * g \end{aligned}$$

- L is dummy which takes the value 1 if a label (or awareness campaign) is present, and g represents the level of government effectiveness (depends positively on protection of property rights, low levels of bureaucracy etc.)
- Also, assume that $\alpha = \alpha(a)$, $\alpha' > 0$, where a represents the level of autocracy of the government

Policy-maker's problem-I

- The policy-maker thus maximises social welfare (S), where

$$S = E(U(\widetilde{a_X})) - D(B)$$

subject to a budget constraint

$$\tau A + \theta^c \delta + \rho R = \overline{T} \quad \text{and}$$

$$\frac{\overline{V_{AX}} - (rAVar(V_{AX}))}{V_{BX}} > \frac{P_A - \tau}{P_B} \qquad (1)$$

$$\theta^c = (\theta^* - \theta), \theta^c \geq 0 \qquad (2)$$

where

$$\theta^* = \frac{\alpha}{\beta}$$

- Proposition: social welfare is higher when B=0 rather than when A=0, i.e. S(A=0)<S(B=0).

  Proof: follows from convexity assumption on damage function, i.e.

$$D'(B) > 0 \text{ and } D''(B) > 0.$$

Policy-maker's problem-II

- Solving using Kuhn-Tucker conditions:

$$\theta^E = \theta^*, i.e. \theta^c = 0$$

$$\tau^E = P_A(\frac{\overline{T} - M_L}{\overline{T} + M_L})$$

$$R^E = \frac{\overline{T} + M_L}{2\rho}$$

Policy-maker's problem-III

Proposition: Once the consumer is perfectly informed about the life of a CFL, he will be indifferent between the two lamps, i.e. CFL and incandescent lamps become perfect substitutes. To ensure sustained CFL consumption, the government would either need to ensure the existence of subsidies, or impose a ban on incandescent lamps.

- Proof: the consumer's problem becomes

$$Max_{A,B}\ E(U(\widetilde{a_X})) = (A\mu + BV_{BX}) \text{ subject to}$$

$$(P_A - \tau)A + P_B B = M_L$$

- The consumer's choice then becomes

A	$(P_A-\tau)/P_B < \mu/V_{BX}$
B	$(P_A-\tau)/P_B > \mu/V_{BX}$
Any combination of A and B	$(P_A-\tau)/P_B = \mu/V_{BX}$

Results

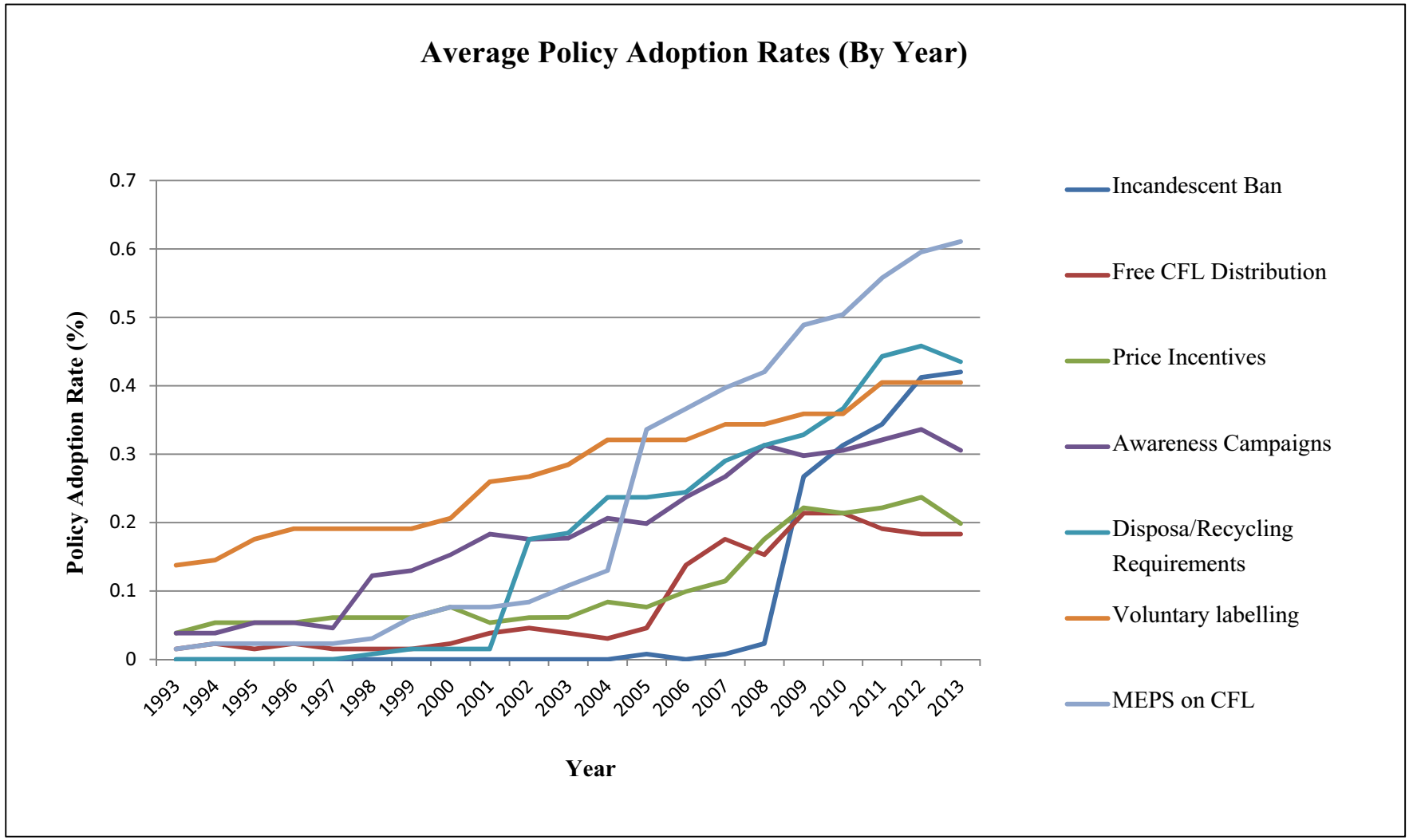
Result 1:

- The consumer will compare the relative price ratio (of A to B) to the ratio of their lifetimes, in deciding between them
- If P_A is significantly higher than P_B, policy-maker will need to subsidize CFL such that $(P_A-\tau)/P_B < \mu/V_{BX}$
- In the absence of a subsidy, or if the subsidy is too low, $(P_A-\tau)/P_B > \mu/V_{BX}$:the policy-maker would then need to ban the use of incandescent lamps, in which case the consumer will be worse off

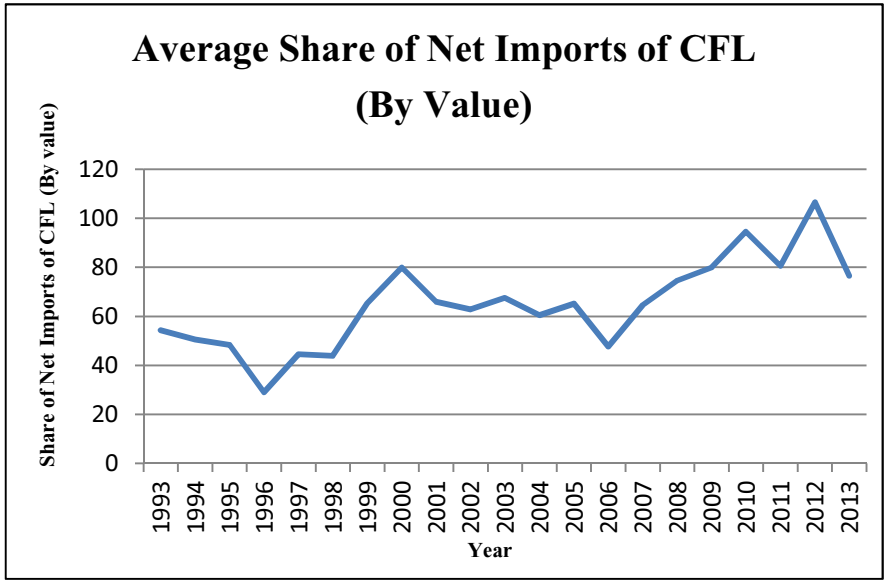
Result 2:

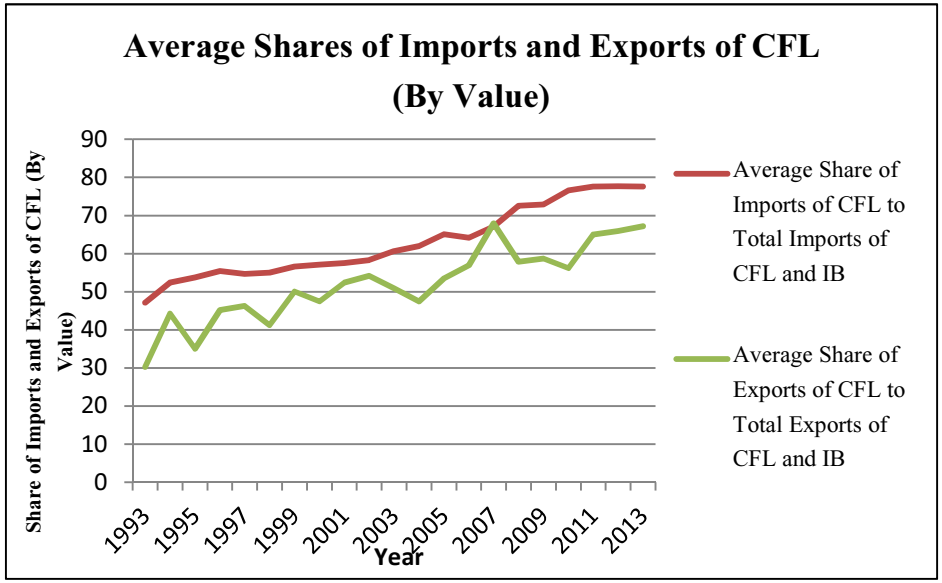
- Consumers in autocracies need to be provided more information to switch to CFL than consumers in democracies

Policy Adoption Rates (By Year)



Summary Statistics on the Dependent Variable





Variable (All defined in terms of value)	Observations	Mean	Std Dev	Missing
(Net Imports of CFL)/(Net Imports of CFL + Net Imports of Incandescents)	1061	67.02	138.85	427
(Imports of CFL)/(Imports of CFL + Imports of Incandescents)	1059	64.16	22.34	429
(Exports of CFL)/(Exports of CFL + Exports of Incandescents)	610	54.07	34.35	828

Summary Statistics of the Independent Variables

Summary Statistics						
Variable	**Obsevations***	**Mean**	**Std. Dev**	**Min**	**Max**	**Missing**
Incandescent Ban	1488	0.05	0.22	0	1	0
MEPS	1488	0.17	0.38	0	1	0
Mandatory and Voluntary Labels	1488	0.08	0.28	0	1	0
Awareness Programs	1488	0.13	0.33	0	1	0
Free CFL Distribution	1488	0.17	0.38	0	1	0
Price Incentives	1488	0.11	0.32	0	1	0
Ratio of Tariffs on CFL to Tariffs on IB	698	0.90	0.48	0	5	790
Trade to GDP	1416	75.10	38.26	11	254.606	72
Trade Agreement Indicator	1488	0.14	0.35	0	1	0
Distance times the share of CFL exports of the 5 largest exporters	1488	5864.62	2471.08	1328	4500.11	0
Polity Index	1378	3.26	5.63	-9	10	110
Sum of Lights	1415	533497.4	1276735	592.29	1900000	73
GDP Per Capita	1448	2297.82	2248.23	122	4235.84	40

Composite Policy Variables	**Observations**	**Mean**	**Std. Dev**	**Min**	**Max**	**Missing**
Regulation	1488	0.16	0.37	0	1	0
Information	1488	0.24	0.43	0	1	0
Price reduction	1488	0.26	0.44	0	1	0

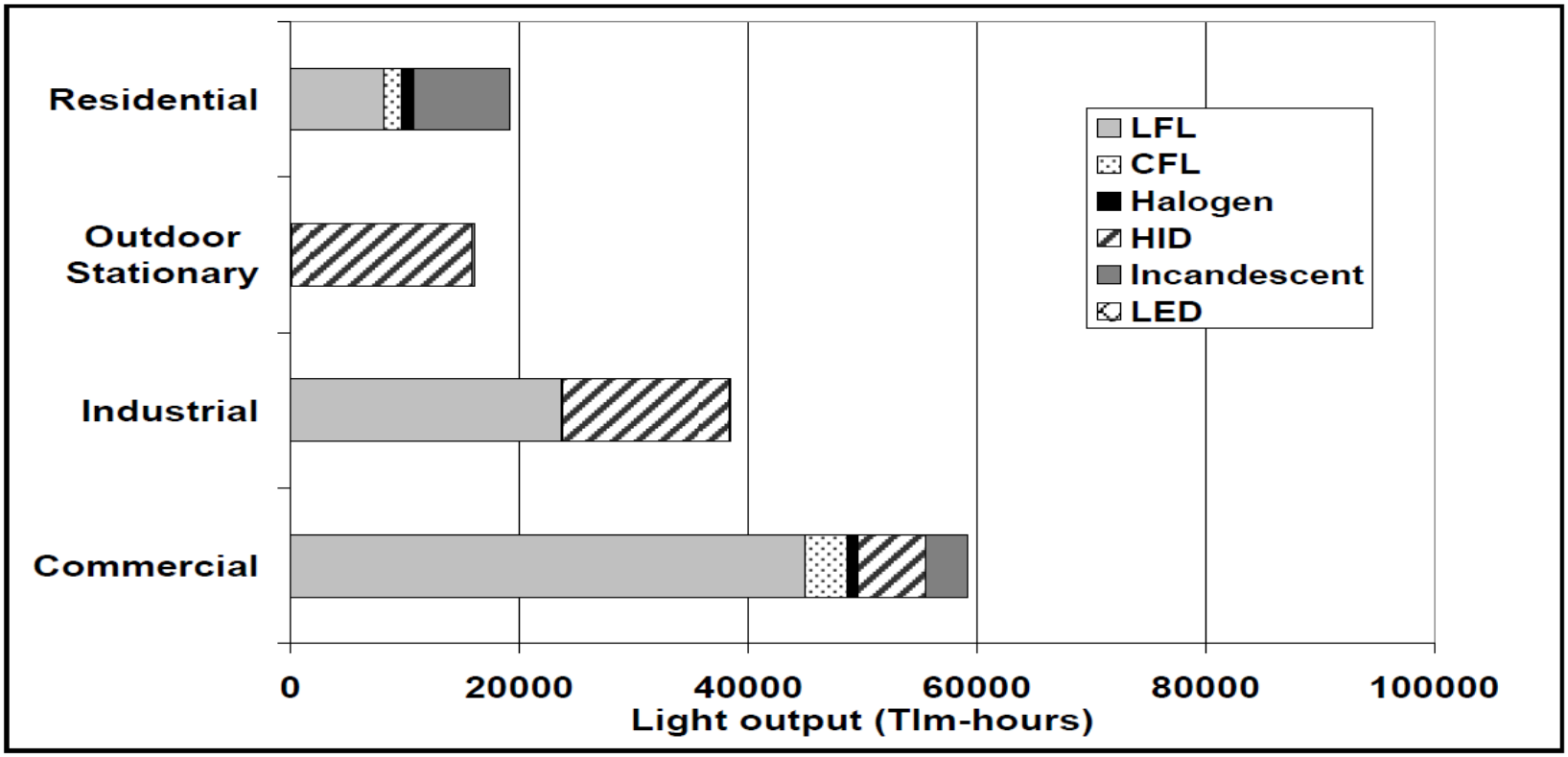
*Country-year observations

Top 5 Exporters in Each Year of the Sample (by Share of Value of CFL Exports)

Year	Top 5 exporters (by share of CFL exports)				
1993	Netherlands	Japan	US	Hungary	UK
1994	Netherlands	United States	Japan	Hungary	France
1995	Netherlands	United States	Japan	France	Hungary
1996	Netherlands	France	Hungary	United States	Japan
1997	Netherlands	France	United States	Hungary	Japan
1998	Netherlands	France	Hungary	China	United States
1999	China	Netherlands	Hungary	France	Poland
2000	China	Hungary	Poland	UK	France
2001	China	Hungary	Poland	France	Canada
2002	China	France	Hungary	Poland	Canada
2003	China	France	Hungary	Poland	UK
2004	China	Netherlands	France	Hungary	Poland
2005	China	Poland	Netherlands	France	Hungary
2006	China	Netherlands	Poland	France	Hungary
2007	China	Poland	Netherlands	France	Hungary
2008	China	Poland	France	Netherlands	Hungary
2009	China	Germany	France	Poland	Netherlands
2010	China	Germany	Poland	France	Netherlands
2011	China	Germany	Poland	France	Netherlands
2012	China	Germany	Poland	France	Netherlands
2013	China	Germany	Poland	France	US

Light Production by Lamp Type

Figure 1: Estimated light production by user sector and lamp type and (2005)



Note: LFL = Linear Fluorescent Lamps; HID = High-Intensity Discharge Lamps; LED = Light-Emitting Diodes. Source: IEA (2006).