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Welfare Effects of Access to Water Service in Cambodia

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Abstract

From data collected by questionnaire survey of three communes in the Kandal province of Cambodia, where public water supply remains inaccessible, this study estimates the demand function for drinking water and finds that the price elasticity is between -0.26 and -0.29. Based on this, and given the price set by the Phnom Penh Water Supply Authority, expansion of service would increase per capita water consumption by 9.8 liters per day, increase consumer surplus by 4.6 percent of total expenditure and decrease the number of households surviving on less than 30 liters of water per day by 5.3 percent. A simulation is used to calculate the water price such that the benefit of water connection exceeds the cost.

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1. Introduction

Several previous studies find a positive effect of piped water access on welfare metrics such as childhood mortality in India (Guillot and Gupta, 2004) and Egypt (Abou-Ali, 2003), and Gini coefficient and poverty head-count ratio in Cambodia (Basani, Isham and Reilly, 2004). In Cambodia, the proportion of the population served with improved water has expanded in recent years but remains low. In 2008, only 55% of the urban population and 5% of the rural population had access to piped water (WHO/UNICEF, 2010). The households that cannot obtain piped water must make do with surface water, wells, rain water, and the like. Piped water service is supplied by both public and private providers. Small private water supply networks serve some areas where public piped water is not available. Surface water is a main water source for small private networks. These private suppliers do not always comply with physical, chemical and biological standards for treating water before distribution (Baker, 2009). They supply water by truck, rickshaw or small-scale supplying infrastructure. Nevertheless, the water tariff of private suppliers is usually several times higher than public water utilities (Garn et al., 2002). This can be a burden for people living in inaccessible areas, who are typically poorer than those living in accessible areas.

Because of the political instability in the past decades, there are so far only a few development case studies that focus on Cambodia. Among them, Garn et al (2002) conducted a survey of the performance of public and private water utilities, in seven towns and one district in 2002. They found that private utilities provided better service quality than did public utilities, but that private utilities also set higher prices. Basani, Isham and Reilly (2008) use the data collected by Garn et al (2002) to study factors that influence access to water and estimated price and expenditure elasticities of the demand for water consumption. They find that high connection fee is an obstacle for poor people to get access to clean water and that the elasticity of water demand ranges between -0.5 and -0.4. Furthermore, they calculate that, if direct connection were to become available for all households in their sample, the Gini coefficient would decrease by three percent and the poverty head-count ratio would improve by six percent.

This paper estimates the welfare gain using similar methods as in Basani, Isham and Reilly (2004). However, there are three differences. First, this paper estimates the welfare effect of access to pipe water based on consumer surplus gains, increase of water volume consumption and improvements for people living on less than 30 liters per day. In contrast, Basani, Isham and Reilly (2004) focused on changes in Gini coefficient and alleviation of poverty. Second, I also analyze the cost and benefit of the project, based on estimates of consumer surplus, and find a range in which Phnom Penh Water Supply Authority can increase its water price and still achieve improved overall welfare. Third, the questionnaire is done in the area around Phnom Penh city which is different from the locations targeted by previous studies. Further, the data is collected from unconnected households, unlike Basani, Isham, and Reilly (2004), who used the data of connected households. Here, "unconnected households" are those living in an area to which water services could be expanded in the future. They currently lack access to public piped water, but they buy water from small private vendors that provide water supply services in their area. Estimating the water demand function using data of unconnected households provides more accurate information on the effect of future water access because the price elasticity of water consumption of unconnected households can be estimated. Using this elasticity, we can better estimate how the public water price reflects on unconnected households, than by using the price elasticity of connected households, because the future benefit of water service expansion is strongly related to unconnected households.

2. Phnom Penh Water Supply Authority (PPWSA)

Recently, with assistance from the international community and good management, PPWSA has developed its capacity for supplying water services. There have been remarkable improvements in water supply coverage, continuity of service, and revenue collection with acknowledged good management.[1] In 1993, there were 26,881 water connections (a mere 20% coverage with respect to total number of households), supply duration was 10 hours a day and operation costs were heavily dependent on government subsidies. In 2008, there were 178,150 connections (85% coverage with respect to total number of households), supply duration was 24 hours a day and operating costs were covered by tariff revenues (Chea, 2009).

PPWSA has undertaken to revise its tariffs in three steps. The first step in June 1997 replaced the previous flat rate with a rate schedule, and the second step in January 2001 raised the rates in each block (See Table I). The tariff schedule is one in which customers who use more water pay a higher rate. This is one element of the government's Poverty Reduction Policy. In general the industrial customers and higher income households that use more water pay more than do others. And those who use little water, which tend to be low-income households, pay less. The tariff rate in the two lowest blocks is actually below the average cost of supplying water which is 900Riels/m^3. The aim has been for PPWAS to extend its service coverage

[1] Some awards have been given for the good management and performance of PPWSA, such as ADB Water Prize 2004, Ramon Magsaysay Award 2006, French Medal 2010 (Légion d'Honneur) and the Stockholm Industry Water Award 2010. The reasons of success and some developments of PPWSA can be found in Araral (2008) and Das et al. (2010).

without overlooking the poor and still maintain financial viability. In addition to the graduated tariff schedule, low-income households have also been given discounts on connection fees and on monthly-installment payments. As of 2008, these discounts have been proffered to more than 17,000 new customers. Water supply capacity in provinces surrounding Phnom Penh is still limited, but there is a new project underway to expand PPWSA service to these areas (Chea, 2006). My goal is to predict the economic benefit of this project based on data gleaned from a questionnaire distributed in three communes targeted for extension of water service.

Table I: Water tariff of PPWSA

Category	Before June 1997	June 1997		January 2001-Present	
		Block (m^3/month)	Tariff (Riels/ m^3)	Block (m^3/month)	Tariff (Riels/ m^3)
Domestic	250 Riels/m^3	≤ 15	300	≤ 7	550
		16-30	620	8-15	770
		31-100	940	16-50	1010
		>100	1260	>50	1270
Administrative		Flat rate	940	Flat rate	1030
Commercials Industrials	700 Riels/m^3	≤ 100	940	0-100	950
		101-200	1260	101-200	1150
		201-500	1580	201-500	1350
		>500	1900	>500	1450

Source: Ek Sonn Chan (2007)

3. The survey

Before commencing my survey, I approached the PPWSA in order to obtain information on target areas for water service expansion from an officer. This helped me determine the targets of this survey, which are three communes in Kandal province, Cambodia: Baekchan, Bakkhaeng, and Praekkompus. The three communes are all in the expansion area but differ in ways relevant to the demand for water services.

The survey was conducted by face-to-face interviews in August 2009. Before conducting the interviews, a pretest was done by interviewing about 10 people in the survey area to ensure that the respondents could understand the questionnaire. After I revised some questions to make them more lucid, the interviews were conducted. First, the interviewers introduced themselves and the purpose of the survey in order to make respondents aware of their status and avoid concerns about any answer to the questions that can possibly be thought to affect the future price setting for their individual households. The questionnaire was in the native language, Khmer[2] and the interviewer read out each question to the respondent.

Table II: Some characteristics of access to water of three communes.

	Baek Chan	Bakkhaeng	Praek Kompus	Total
. Percentage of water expense to total expenditure (%)	6.2%	3.2%	6.6%	5.7%
. Average monthly water volume per household (m^3/month)	10.84	11.48	17.88	14.65
. Current water price (Riel/m^3)	2915	1796	4500	2770
. Buy water from private operator	46	22	13	81
. Observation Number	54	37	89	180
. Main water source	Pond	River	Well	

The questionnaire consists of three main groups of questions. The first group of questions pertain to the respondents' socio-economic data such as age, number of family members, occupation etc. The second group of questions is about current water usage such as water source and monthly volume of water consumption[3]. The third group of questions is about the household's monthly expenditures[4] and on what assets the household such as motorbike, television, electric fan, cow etc. In all, 180 households (90% of the planned sample size of 200 households) agreed to be interviewed. The detailed results of the second group of survey questions for each of the three communes are summarized in Table II.

4. Methodology and Descriptive Statistics

4.1. Demand Function and Elasticity of Substitution

A demand function is estimated to calculate the price and expenditure elasticity of substitution. The expenditure is used instead of income because respondent is likely to understate their income. In the questionnaire, the question on the expenditure is asked before that

[2] Khmer is the official language of Cambodia.

[3] For some households which buy water from private vendor through rickshaw or truck delivery, we ask number of barrels they buy monthly and calculate with total volume of water purchase by multiplying with storage volume of barrel.

[4] The household's income is also asked after expenditure, but as most of them are likely understated the amount below the expenditure, the expenditure and asset are used instead of income in this study.

of income. Surprisingly, households give a lower income than expenditure. Therefore, expenditure data, asset of family and other controlled variables are used. Similar method is also used in Basani, Isham and Reilly (2004, 2008).

The water demand function is Q = Q (expenditure, waterprice, **Z**), where *Q* is volume of water consumption per capita, *expenditure* is monthly expenditure per capita, *waterprice* is the flat-rate price of water paid by a household to buy 1m^3 of water volume from a private vendor, and **Z** is a vector of household characteristics used as control variables. The demand function in log-linear form can be written as:

$$\ln Q_i = \alpha + \beta \ln(expenditure)_i - \gamma \ln(waterprice)_i + \beta_i Z_i + \varepsilon_i \qquad (1)$$

where β is expenditure elasticity of substitution, γ is water price elasticity of substitution and ε_i is error term.

4.2. Consumer surplus based on price change

For the case study of Cambodia, Basani, Isham and Reilly (2004) uses the price paid by already-connected respondents to calculate the consumer surplus. In this paper, the price paid by not-yet-connected households is used and it is higher than the water price of PPWSA. The Consumer surplus is calculated following the same method as Strand and Walker (2003).
First, the non-stochastic part of equation (1) can be rewritten as

$$\ln Q_i = \alpha + \beta \ln(\exp enditure)_i - \gamma \ln(waterprice)_i + \beta_i Z_i$$

Rewriting it in this form,

$$\ln Q_i = A(i) - \gamma \ln P_i \qquad (2)$$

where $P_i = waterprice_i$; $A(i) = \alpha + \beta \ln(\exp enditure)_i + \beta_i Z_i$

$A(i)$ is assumed to be independent among household.

The consumer surplus is obtained as in equation (3), (the calculation is available in Appendix).

$$CS = \frac{P_i Q_i}{1-\gamma}\left[1 - \left(\frac{P_0}{P_i}\right)^{1-\gamma}\right] \qquad (3)$$

4.3. Cost and Benefit

From equation (3), the total benefit of the project is calculated using average consumer surplus, discount rate and life-span of transmission mains. Suppose that ρ is the discount rate which is equal to long-term interest rate, 0<ρ <1, and t is life-span of water supply main, commonly 50 years.

The present value of connection benefit to each household (PVB) is

$$PVB = CS + \frac{CS}{1+\rho} + \frac{CS}{(1+\rho)^2} + \dots\dots + \frac{CS}{(1+\rho)^t} = \frac{CS\left[1-\left(\frac{1}{1+\rho}\right)^{t+1}\right]}{1-\frac{1}{1+\rho}} \cong \frac{CS}{1-\frac{1}{1+\rho}} = CS\,\frac{1+\rho}{\rho} \tag{4}$$

The project should be implemented if the cost of connection is less than total present value of project. The current connection fee of PPWSA is around 400,000 Riels (approximate 100USD).

4.4. Descriptive Statistics

The sample size is 180, which is 90% of our target number 200, as some households refused to be interviewed. After removing outliers and incomplete responses from the sample, the sample size is 147. Some households use their own water sources such as wells, for which there is no data on water price and these observations are excluded from the estimation. So, in this study, the data used for estimating the price elasticity in equation (1) is that of the households who buy water from private vendors.

Watervolume is monthly volume consumed per capita. It is the total amount of water consumption by the household divided by the number of household members. *Waterprice* is the amount of money spent to buy 1m^3 of water volume from a private seller. The price differs among the three communes depending on the characteristics of the water source, location or water delivery methods. *Expenditure* is total expense per capita, defined as the ratio of household's monthly expenditure to the number of household member. In this paper, *Expenditure* is used instead of income as most of respondents tend to understate their income relative to their expenses. During the interview, the expenditure is asked before the income. In the estimation, household assets are also used as control variables. These include televisions, electric fans, and the like which may represent the household's wealth (similar method as Basani, Isham and Reilly, 2008). The summary statistics for the variables are in Table III.

Table III: Data Statistics

Variables	Definition	Mean	Std.Dev	Min	Max
Watervolume	Monthly water consumption per capita (m^3)	2.10	1.83	0.16	10
Waterprice	Water tariff paid for 1 of water(Riel/m^3)	2771	1374	380	6250
Expenditure	Monthly total expenditure per capita (10,000 Riels)	10.7	5.81	0.93	31
TV	Number of television that households owns	1.10	0.57	0	3
Motorbike	Number of motorbike that households owns	1.05	0.81	0	4
Telephone	Number of telephone that households owns	1.68	1.26	0	6
d_toilet	1 if water is used for toilet 0, otherwise	0.64	0.48	0	1
d_commercial	1 if household owns business for which water is used as intermediate good. 0, otherwise.	0.25	0.43	0	1

5. Estimation Result

The price and expenditure elasticity of water consumption are estimated with two models. In the first model, the only independent variables are water price and total expenditure. In the second model, in addition to price and expenditure, other control variables such as household assets and characteristics are also included. Concerning the multi-collinearity problem, the mean vif value is estimated for both models. For both models, the mean vif value is not more than 1.3, indicating that multi-collinearity is not a problem (See Table IV). The Breuch-Pagan test of heteroskedasticity is also conducted and the results validate the assumption of constant variance for both models. The result of OLS regression demonstrates that price elasticity is between -0.29 and -0.26 and expenditure elasticity is between 0.59 and 0.65 (See Table IV).

My results may be compared with the estimates of Basani, Isham and Reilly (2008) for seven towns and one district. They found that price elasticity was between -0.5 and -0.4 and the expenditure elasticity was around 0.2. My results show that for the households living in the three communes, the price elasticity of demand for piped water is relatively low, possibly reflecting the higher living standard of households in the three communes compared to those in the provincial areas used in the study of Basani, Isham and Reilly (2008).

From the result of both estimation models, the average price elasticity estimated in this paper is -0.275. From this, let us predict the improvement of water consumption conditions and increase in consumer surplus which can be gained if the water is supplied at the current price of PPWSA. With the relatively lower price of PPWSA, the water consumer can save some money and improve water consumption (Table V). From the result, approximately 4.6% of total expense can be saved from the cheaper water price.

Table IV: Estimation of Water Demand Function

Dependent Variable ln(water volume)	**Model1**	**Model2**
ln(waterprice)	-0.29**	-0.26*
	(0.145)	(0.155)
ln(expenditure)	0.59***	0.65***
	(0.147)	(0.145)
TV		0.20
		(0.166)
Motorbike		-0.13
		(0.128)
Telephone		0.10*
		(0.086)
d_commercial		0.48**
		(0.200)
d_toilet		-0.09
		(0.188)
Constant	-4.10**	-5.29**
	(2.076)	(2.144)
Mean vif	1	1.3
Observation	76	76
Adj R-Square	0.20	0.29

Note: In parentheses is standard errors. (***), (**), (*) present p-value at significance level of 1%, 5%, 10% respectively.

Table V: The benefit to be gained from PPWSA current price

	Water price of private vendor	Current block rate price of PPWSA
. Percentage of household consuming less than 30 liters per day (%)	23.7	18.4
. Mean water volume per capita (liters/day)	70.1	79.9
. Percentage of increased water consumption volume (%)	0	13.9
. Ratio of consumer surplus gain to total expense (%)	0	4.6

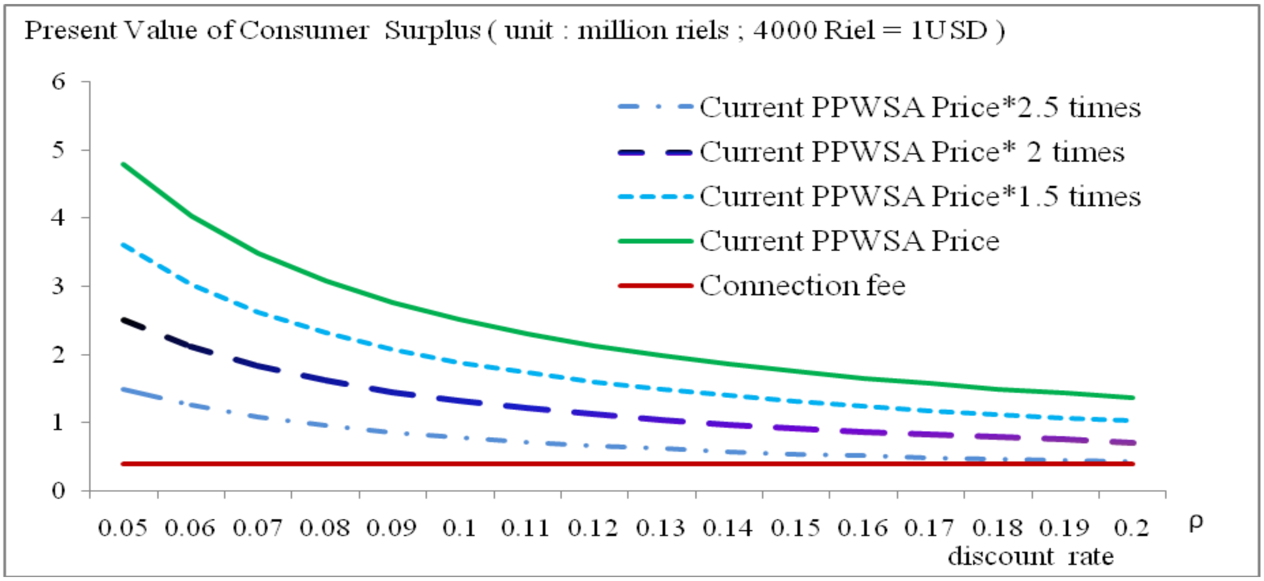
Moreover, according to the guidelines of WHO (2005), to meet health standards, the minimum level of water volume needed for each person for drinking, cooking and personal washing is 30 liters per day. Of the 76 households in the sample who bought water from private providers, 23.7% of them live on water less than the standard level. This can reflect the low living standard, high water price or difficulty of access to water. Using the estimnated price elasticity, if the water is supplied at the current water price of PPWSA, the percentage of households living under this standard would decrease from 23.7% to 18.4%. Similarly, average water volume per capita would increase from 70.1 liters per day to 79.9 liters per day, a 13.9% increase in water consumption compared with current water consumption bought from private vendors. The percentage improvement can actually be higher than the above results if we take into account improvements in the convenience of water access and improvement in quality in addition to price effects. Consumer surplus is calculated using equation (3) with average estimated price elasticity in the two models equal to -0.275 and P_o equal to the current water price of PPWSA. The result shows that the consumer surplus can increase by 4.6% of household total expenditures with current water price of PPWSA.

The present value of connection benefit is calculated using equation (4) with the average consumer surplus discount rate equal to the long-term interest rate. The interest rate in Cambodia is fairly high on average, 7.65% per annum in 2008 (ADB 2009) and it slightly fluctuates yearly. As the interest rate is not exactly determined, in the simulation, discount rate evolves from 5% to 20% to calculate the total benefit of connection. Figure 1 presents value of benefit that each household may gain from connection. For example, if the interest rate is 7%, the total present value of benefit from PPWSA service connection with current price is about 3.4 million Riels (approximately 870 USD). Comparing to connection cost of 400,000 Riels (approximately 100USD) for a water meter and 10-meter-long pipe, the total household benefit is several times higher than the cost. That can be even higher if considering the improvement in health when using the well-treated water.

According to population census done by National Institute of Statistics of Cambodia in 2008, population density in Kandal province (i.e. targeted location) is 12.8 times lower than that of Phnom Penh city. As densely populated area may serve with a cheaper water price as cost on network infrastructure can be lower (Estache and Rossi, 2002), we can consider possible price disparity between Phnom Penh city and survey area that may be implemented to cover the cost of infrastructure. Figure 1 presents some results of present value of consumer surplus for various assumed water prices. The simulation is done with some alternative prices: current block-rate PPWSA price, 1.5 times current block-rate PPWSA price, 2 times current block-rate PPWSA price, 2.5 times current block-rate PPWSA price. As the interest rate is fairly high in Cambodia, the discount rate is set to evolve from 5% to 20%.

From the result, we find that, the benefit gain is much higher than the connection cost. With the simulation, the consumer surplus curve shifts down toward the connection cost, just equaling it when the price is approximately 2.5 times current PPWSA. This is one indication of the net social benefit that the current water price bestows on each household. The result can intuitively mean that there is a social benefit if more households were to connect to PPWSA rather than using their own wells. So, the expansion of water supply to surrounding area of Phnom Penh by PPWSA is important to economic development.

Figure1: Simulation of water price and consumer surplus gain



6. Conclusion

The paper investigated the benefit of future water service expansion using survey data of water usage in three communes in the area surrounding Phnom Penh city, Cambodia. From the estimation, this study finds that the expansion would increase dwellers' well-being. If Phnom Penh Water Supply Authority were to supply water in those areas at its current block-rate price, it would improve the water consumption and consumer surplus. From this study sample, the expansion of water by PPWSA would decrease the population living below standard water consumption level of 30 liters per day by 5.3 percent, increase average per-capita water consumption by 9.8 liters per day, and increase the purchasing power of household's total expenditures through consumer surplus gain of 4.6 percent.

Further, from the result of simulation of water prices, average benefit to each household of the current PPWSA price is higher than the water connection fee. The benefit becomes similar to connection fee when the price becomes 2.5 times higher than the current price. So, the current PPWSA water price would imply high average benefit per household. Therefore, households would tend to make water connection when there is service expansion to their area at the current price. Further research on willingness-to-pay for water tariff and connection fee at targeted location may be helpful for setting future policy on water price, to make the service accessible until the poorest households.

Appendix: Consumer Surplus

The calculation follows the same method as Strand and Walker (2003). However, this paper assumes price of PPWSA is lower than current price of private suppliers, (i.e. $P_0 < P_1$).

We have, $\ln Q_i = \alpha + \beta \ln(expenditure)_i - \gamma \ln(waterprice)_i + \beta_i Z_i$ (1)

Rewriting it in this form,

$\ln Q_i = A(i) - \gamma \ln P_i$ (2)

where $P_i = waterprice_i$; $A(i) = \alpha + \beta \ln(expenditure)_i + \beta_i Z_i$

$A(i)$ is assumed to be independent among household.

From (2), we obtain $Q_i = e^{A(i) P_i^{-\gamma}}$ or $P_i^{\gamma} = e^{A(i)} / Q_i = e^{A(i)} Q_i^{-1}$ (3)

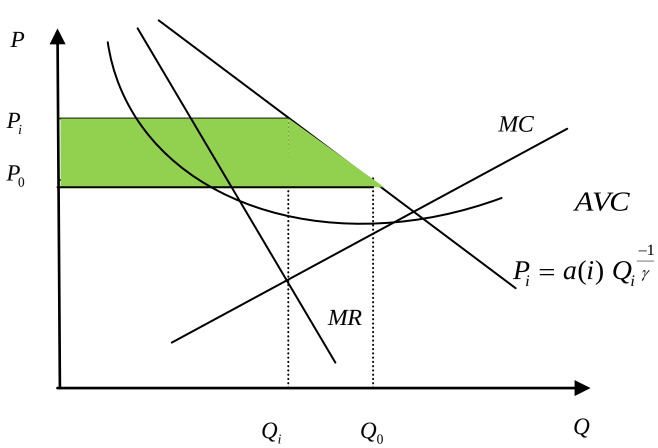
$$P_i = e^{\frac{A(i)}{\gamma}} Q_i^{\frac{-1}{\gamma}} = a(i)\ Q_i^{\frac{-1}{\gamma}} \quad \text{where} \quad a(i) = e^{\frac{A(i)}{\gamma}} = P_i Q_i^{\frac{1}{\gamma}} \tag{4}$$

Because $A(i)$ is assumed to be independent among households, $e^{A(i)}$ and $a(i)$ are also independent. From Figure 2, the consumer surplus (CS) can be calculated by

$$CS = \int_{Q_i}^{Q_0} P_i\, dQ + P_i Q_i - P_0 Q_0 \tag{5}$$

where P_i denotes current water price paid to a private vendor and Q_i is volume of current water consumption. P_0 is water price determined by PPWSA, which is expected to be lower than the private vendor's price P_i. And Q_0 is water consumption when price is equal to P_0

Figure 2: Consumer Surplus



Replacing P_i of equation (4) into (5), we obtain,

$$CS = \int_{Q_i}^{Q_0} a(i) Q_i^{\frac{-1}{\gamma}} dQ + P_i Q_i - P_0 Q_0$$

$$= a(i)\left[\frac{Q^{\frac{-1}{\gamma}+1}}{\frac{-1}{\gamma}+1}\right]_{Q_1}^{Q_0} + P_i Q_i - P_0 Q_0$$

$$= a(i)\frac{\gamma}{\gamma-1}\left(Q_0^{\frac{\gamma-1}{\gamma}} - Q_i^{\frac{\gamma-1}{\gamma}}\right) + P_i Q_i - P_0 Q_0$$

$$= a(i)\left(Q_0^{\frac{\gamma-1}{\gamma}} - Q_i^{\frac{\gamma-1}{\gamma}}\right) + a(i)\frac{1}{\gamma-1}\left(Q_0^{\frac{\gamma-1}{\gamma}} - Q_i^{\frac{\gamma-1}{\gamma}}\right) + P_i Q_i - P_0 Q_0 \quad (6)$$

From (4) $P_i = a(i)\, Q_i^{\frac{-1}{\gamma}}$, then $P_i\, Q_i = a(i)\, Q_i^{\frac{\gamma-1}{\gamma}}$

Similarly, when price equals P_0, $P_0\, Q_0 = a(i)\, Q_0^{\frac{\gamma-1}{\gamma}}$.

Substitute these into (6), we obtain $CS = \frac{a(i)}{\gamma-1}\left(Q_0^{\frac{\gamma-1}{\gamma}} - Q_i^{\frac{\gamma-1}{\gamma}}\right)$. (7)

From (4), $a(i) = P_i\, Q_i^{\frac{1}{\gamma}}$. Substituting this into (7), we get

$$CS = \frac{P_i Q_i^{\frac{1}{\gamma}}}{\gamma-1}\left(Q_0^{\frac{\gamma-1}{\gamma}} - Q_i^{\frac{\gamma-1}{\gamma}}\right) = \frac{P_i}{\gamma-1}\left(Q_i^{\frac{1}{\gamma}} Q_0^{\frac{\gamma-1}{\gamma}} - Q_i\right)$$

$$= \frac{P_i Q_i}{\gamma-1}\left(\left(\frac{Q_0}{Q_i}\right)^{\frac{\gamma-1}{\gamma}} - 1\right) = \frac{P_i Q_i}{1-\gamma}\left(1 - \left(\frac{Q_0}{Q_i}\right)^{\frac{\gamma-1}{\gamma}}\right) \quad (8)$$

From (3) $P_i^{\gamma} = e^{A(i)} Q_i^{-1}$, $e^{A(i)} = \frac{P_i^{\gamma}}{Q_i^{-1}}$

As $e^{A(i)}$ is independent from household, we have $e^{A(i)} = e^{A(0)}$.

Then, $$\frac{P_i^{\gamma}}{Q_i^{-1}} = \frac{P_0^{\gamma}}{Q_0^{-1}} \quad \text{or} \quad \frac{Q_0}{Q_i} = \left(\frac{P_0}{P_i}\right)^{-\gamma} \tag{9}$$

Replace (9) into (8), the consumer surplus of household is:

$$CS = \frac{P_i Q_i}{1-\gamma}\left[1 - \left(\frac{P_0}{P_i}\right)^{1-\gamma}\right]$$

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