**Optimal Carbon Prices Worldwide**

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*Extended Abstract*

In this paper, we derive optimal carbon prices at the world level. We model heterogeneous consumers’ behavior distinguished by geographical zones. Using empirical estimations of household behavior, we compute demand elasticity values for the 70 most important countries in the world, which constitute 90% of the total world energy consumption and emissions. We compute carbon prices differentiated by country, according to a Ramsey optimal scheme. This is a new approach in the climate change policy. Our results show that the optimal pricing scheme can improve world welfare and promote a reduction in total emission.

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**1. Introduction**

In the policy debate at the world level, carbon price is considered a crucial instrument to achieve emission reduction toward sustainable climate change policy.

However, the classical solution of computing a marginal social damage to be added to the marginal private cost has not proved viable. To prove this latter point , it suffices to recall the bitter confrontation between developed economies and emerging economies, showing different preference structures.

It is evident that the public good nature of climate change policy constitutes a departure from the perfect competitive model.

In this context, the carbon price has to be different from the private marginal costs, pointing to the need for a second best solution, in so far as there are heterogeneous preferences across countries in the world. This problem finds a theoretical solution in setting a Ramsey (1927) price scheme, which allows to minimize the deadweight losses associate with the market inefficiencies.

The aim of this paper is to design an optimal carbon price to finance the carbon emission reduction policy, making explicit use of households’ preferences worldwide.

Surprisingly, the vast literature on carbon price has not used this analytical tool to propose a burden sharing mechanism of the cost of climate policy. We deem that this could be one of the reasons at the root of the failure of the political process (failure of Cop Conferences and we think that Paris will be a failure, too), because the traditional approach is to design the individual country commitment proportional to emissions, or else GDP size, valued at a common marginal price.

In this paper, we use empirical estimation of the households price elasticity of energy consumption (directly related to emissions), which is a revealed preference measure of the willingness to pay for energy consumption, and indirectly, for the willingness to pay for the (negative of) emission reduction.

The inverse of the demand elasticity is used to compute the Ramsey proportionality factor to compute the burden sharing of the world climate policy for each country.

There are consolidated applications of the Ramsey method in both theoretical and empirical economic analysis in the public utility sector, starting from the seminal contribution of Laffont and Tirole (1996), discussing the Ramsey optimality of the price cap regulation.

This paper is organized as follows. Section 2 presents a brief review of the related literature. Section 3 presents the theoretical framework of optimal pricing and the empirical methodology to estimate consumer behavior and describes the data set used. Section 4 presents the results and the discussion and concludes the paper.

2 The Ramsey literature

There are many relatively recent applications related to the electricity markets. Qi et al. (2008) compute Ramsey prices for the Chinese residential sector and Matsukawa et al. (1993) analyze the Japanese utility sector. They both conclude that the welfare effects of rate regulation could be improved by increasing the residential electricity price and decrease the industrial one. Horowitz et al. (1996) discuss the case of unknown bypass costs. Berry (2000 and 2002) discusses Ramsey pricing as a tool for the regulator to discriminate between liberalized and bundled customers and to charge optimally stranded costs. The conclusion is that unbundled customers are more elastic, because they can search for alternatives in the market, and therefore their optimal Ramsey price should be lower than that charged to bundled customers.

On the theoretical ground, Ramsey pricing promotes efficiency by minimizing the deadweight welfare loss resulting from maintaining the budget equilibrium, but does not address at all the issue of equity. In this paper we do not consider the instruments to correct for equity, which have been implemented in practice after the liberalization of electricity markets, such as income transfer or considering agents relative conditions in terms of expenditure marginal utility (Diamond 1975).

In general, the economic theory recommends adopting Ramsey pricing when the marginal cost for setting the price is not sufficient to collect the necessary revenue.

We deem that this is precisely the situation of the worldwide climate change policy.

There is a vast literature on the free-riding (e.g. Bigerna Bollino Micheli, 2015) and on the fact that political negotiations cannot reach an agreement on the right amount of resources to be committed to this policy.

In this case, the extra-cost over the pure market price of energy represents revenue that needs to be collected in the least distortionary manner to finance the climate policy. In other words, Ramsey pricing is an ideal solution to discriminate among countries worldwide, according to the preferences expressed by their consumers, who directly reveal their willingness to pay for such commitment.

It is somehow surprising, therefore, to note that there is not in the literature, to the best of our knowledge, an application of Ramsey pricing to this issues.

**3. Optimal pricing and demand behavior**

We assume that the cost functions for each buyer *j* (representative of zone *j)* at each stage are of the standard form: *cj = cj (p, uj)*, where the cost is a function of utility and prices. Standard duality theory allows to invert the cost function into an indirect utility function, from which Roy’s identity yields the usual Marshallian demand functions for each group *k* in the first stage and for each hour *h* in the second stage, for each buyer *j*:

*ekj =ekj(p,Ej) k =d,n (1)*

*ehj =ehj(pd,Edj) h = 10, 11, … ., 21 (2)*

*ehj =ehj(pn,Enj) h = 22, 23, …, 9 (3)*

where the price vector in the first stage is: *p=(pd, pn)* and in the second stage is: *pd=(p10,….,p21)* during the day and *pn=(p22,…..,p9)* during the night. *Ej* is total expenditure of buyer *j* and, in the second stage, *Edj* is total expenditure in the day and *Enj* is total expenditure in the night.

We assume that the policy maker has knowledge of individual demand functions and is willing to charge a Ramsey pricing to compute the efficient price without transmission line congestion and wants to determine the optimal charge *thj* to be levied in each hour *h* to each group of buyers in zone *j*, which has to be added to the price in order to satisfy the constraint that total market revenues equal total market costs:

*phj\*=peh + thj (4)*

In eq. (4) the optimal Ramsey price is defined as the sum of the efficient price and the zonal optimal tax in each hour *h*. This entails computing for each hour *h* optimal prices for all zones *j* according to the classic Ramsey (1927) formula:

*[(p\*hj - peh)/peh] / [(p\*hi - peh)/peh] = (1/|εhj|) / (1/|εhi|) (5)*

subject to the constraint*:*

*G = ∑pjhejh = ∑pjh\*ejh (6)*

i.e., the charges over the efficient price are inversely proportional to the demand elasticity, where *p\*hj* and *p\*hi* are optimal prices, *phj* are historical zonal prices, *ehj* are quantities, *εhj* are estimated own price elasticities[[1]](#footnote-1) for each hour *h* and zones *i* and *j*.

Notice the crucial feature that revenue *G* is derived charging *thj* to each consumer *j* according to his/her consumption behavior. In this case, consideration is not given for distributive equity but only for efficiency; thus, charges are higher for inelastic goods with respect to more elastic goods.

4. Empirical results and Discussion

We construct the data for household sector energy consumption, for 117 countries from 2000 to 2013.

Prices are in constant 2005 dollars. Quantities are in TOE for residential uses and transportation. Thus, total energy expenditure is the actual expenditure of households for all energy uses. In this way, we capture the households’ preferences for direct usage of energy for all households needs.

We report the comparison between the equi-proportional and optimal taxation by country.

Notice that equi-proportional implies that a country contributes to the world burden sharing in proportion to her size (of consumption expenditures), i.e. her level of well-being.

In conclusion, we advocate a new policy stance worldwide, using the estimated consumer demand elasticity as the basis to differentiate carbon price worldwide.

References

AEEG, Autorità Per L'energia Elettrica e Il Gas, 2008. Relazione Annuale alla Commissione Europea sullo stato dei servizi e sulla regolazione dei settori dell’energia Elettrica e del gas, Milano. Available at: <http://www.autorita.energia.it/allegati/relaz_ann/08/E08_NR_Italy-LL_V2.pdf>.

Bigerna, S., Bollino, C.A., 2014. Electricity demand in wholesale Italian market. Energy J. 35, 25-46.

Bigerna, S., Bollino, C.A., 2015. A system of hourly demand in the Italian electricity market. Energy J. 36, 1-19.

Bigerna, S., Polinori, P., 2014. Italian households' willingness to pay for green electricity. Renew. Sustain. Energy Rev. 34, 110–121.

Bollino, C.A., 1987. Gaids: a generalized version of the almost ideal demand system. [Econ. Lett.](http://ideas.repec.org/s/eee/ecolet.html) 23, 199-202.

Diamond, P.A., 1975. A many-person Ramsey tax rule. J. Public Econ. 4, 335-342.

GME, 2013. Annual Report. Rome. Document Available online at:

<http://www.mercatoelettrico.org/en/GME/Biblioteca/RapportiAnnuali.aspx>

Kopsakangas-Savolainen, M., 2004. The welfare effects of different pricing schemes for electricity distribution in Finland. Energy Policy 32, 1429-1435.

Laffont, J.J., Tirole, J., 1996. Creating competition through interconnection: Theory and practice. J. Regul. Econ. 10, 227-256.

Lin, B., Liu, J., 2011. Principles, effects and problems of differential power pricing policy for energy intensive industries in China. Energy 36, 111-118.

Matsukawa, I., Madono, S., Nakashima, T., 1993. An empirical analysis of Ramsey pricing in Japanese electric utilities. J. Jpn. Int. Econ. 7, 256-276.

Nahata, B., Izyumov, A., Busygin, V., Mishura, A., 2007. Application of Ramsey model in transition economy: A Russian case study. Energy Econ. 29, 105-125.

Pazhooyan J., Mohammadi T., 2000. Optimal Ramsey pricing for Iranian electricity industry. Iran. Econ. Res. 3, 39-61.

Qi, F., Zhang, L.Z., Wei, B., Que, G.H., 2009. An application of Ramsey pricing in solving the cross-subsidies in Chinese electricity tariffs. IEEE, Institute of Electrical and Electronics Engineers, 442–447.

Ramsey, F.P., 1927. A contribution to the theory of taxation. Econ. J. 37, 47-61.

Shepherd, W.G., 1992. Ramsey pricing: Its uses and limits. Util. Policy, 2, 296-298.

Wedig, G.J., 1993. Ramsey pricing and supply-side incentives in physician markets. J. Health Econ. 12, 365-384.

1. Given the two-stage structure of the demand system, we need to use unconditional elasticities for each hour in eqs. (2)-(3), which depend on both aggregate and hourly behavior. Detailed description of the formulae to recover from estimated parameters the unconditional elasticities under weak separability in two-stage demand systems can be found in Bigerna and Bollino (2014) and Edgerton (1997). [↑](#footnote-ref-1)