

On the significance of pre-existing distortions for the costs of environmental regulation^{*}

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Abstract

Recently, several papers have shown that environmental taxes are more costly in an economy with preexisting distortions than in an undistorted economy. This result applies for equal percent reductions from different emission levels. We investigate the introduction of a common target emission level in such economies, and find that the restriction reduces the initial efficiency-difference between the economies; the two solutions may even coincide. Thus, it is less costly to achieve a target for environmental quality in the distorted economy. Our result complements the above-mentioned conclusions on environmental policy in economies with and without preexisting distortions.

Keywords: Environmental taxes, excess burden, tax reform

JEL Codes: D58, D62, H21, H23

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1. Introduction

Environmental taxation and green tax reforms have been studied extensively during the last few years. Many analyses have focused on the significance of pre-existing distortions for environmental policy. This particular topic became highly popular when the idea emerged that environmental taxes may yield a double dividend if the revenues from these taxes are used to reduce the rates of existing, distortionary taxes (cf. Pearce (1991)).

Our contribution to this literature is motivated by a result obtained in three related studies by Goulder et al (1997), Parry et al (1999) and Goulder et al (1999), henceforth GP. In all three papers, the authors compare the marginal cost of emission reductions in cases with and without pre-existing, distortionary taxes.¹ They find that the marginal cost schedules in the second best are located above the corresponding cost curves in first best (no prior taxes) economies, i.e., the marginal costs are highest for the economies with pre-existing taxes.² This is an interesting and striking result, since it may be viewed as the antithesis of the original idea of a double dividend: Pre-existing tax distortions in fact make environmental regulation *more costly* than if the economy were in a first best situation.

Rather than compute the marginal cost of *per cent reductions* from different initial emission levels, we analyse the welfare cost of imposing an *emission target*, i.e., a restriction on the emission *level*. We see two main reasons for this approach, one theoretical and one empirical. A positive analysis in order to understand the implications of a first vs. a second best starting point should observe that there are several differences between economies with and without pre-existing tax distortions – apart from the distortionary taxes themselves. In fact, the only common element in model solutions is the exogenous tax revenue requirement, while commodity prices, income, quantities of intermediate and final goods, and thereby also emission levels, differ. Our approach may be seen as a standard comparative statics exercise. We impose two restrictions, i) the total tax revenue must be greater than or equal to a revenue requirement, and ii) the emission level must be less than or equal to an emission target. We then study the effects of tightening the emission restriction given a revenue level. Since emissions in unregulated first- and second best economies differ, emissions in the first best being higher, the emission restriction ii) is initially non-binding in the second best economy.

¹ Goulder et al (1997) consider SO₂ emissions, Parry et al (1999) CO₂ emissions, and Goulder et al (1999) NO_x emissions. In all papers, a comparison of costs of emission reductions in first- and second best is only one of several interesting topics, but this particular topic is the one we focus on here.

² Cf. Figure 1 in Goulder et al (1997), Figure 1 in Parry et al (1999), and Figure 1 in Goulder et al (1999).

The observation that a second best setting leads to a lower emission level is fairly intuitive, and has been made before, see e.g. Lee and Misiolek (1986) and Schöb (1996, 1997). This observation also relates to the result by Atkinson and Stern (1974) that one cannot infer from the modified Samuelson rule for distorted economies that the public good provision will be lower in a second best world compared to the provision in a first-best world. Considering environmental quality a public good provides the link.

Our second motivation is that the costs from damages caused by emissions are related to the levels of emissions and not percentage reductions. Viewing a static model as a reduced form representation of an intertemporal reality with feedbacks from a damaged environment, the emission level provides the more relevant indicator or target. Of course, present political negotiations over who should reduce their emissions by how much are phrased in terms of percentage reductions. The long-term issue, however, seems to be an evaluation of what would be the optimal emission level or time profile of emissions.

Our main result is that *the additional welfare cost in a second best economy compared to a first best economy* becomes smaller the tighter the emission restriction. The intuition is quite simple. At the outset, without binding restrictions on emissions, tax revenues stem from entirely different tax bases. In the undistorted economy there is a lump sum tax, while in the distorted economy there is a tax on labour income. A revenue-neutral, green tax reform provides a common tax base which, roughly speaking, makes the two tax solutions more similar. In principle, the two solutions may coincide. This would be the case when the revenue from the emission tax meets the revenue requirement, which would obtain when both the emission target and the revenue requirement are sufficiently low. The introduction of an emission restriction therefore leads to *efficiency-convergence* between the undistorted and the distorted economies. This result confirms an observation made by Sandmo (1995). He argued that the substitution of environmental taxes for pre-existing distortionary taxes might remove the excess burden completely. (See also Oates (1995).) We demonstrate this result in Figure 2 below.

The remainder of this paper is structured as follows. In Chapters 2 and 3 we lay the theoretical basis from public finance. In particular, we introduce notation in Chapter 3 in order to make the interpretation of our results precise. Chapter 4 reports on our numerical analysis from the CGE model by Parry et al (1999).³ Finally, Chapter 5 concludes.

³ An appendix containing our coding of their model in the MPSGE/GAMS-format is available from the authors. Running this model reproduces both their results and ours.

2. Theoretical foundations

We have re-established the numerical model in Parry et al (1999). This is an eight-sector CGE-model of the US economy involving only a few alternative tax instruments. It is an easy task to compute the first- and second best solutions of the model, and it suits our goals nicely. Furthermore, re-using Parry et al's model facilitates direct comparisons with their results. We do not believe that the qualitative aspects of our results are specific to this particular model, however.

In their model economy the Diamond-Mirrlees (1971) production efficiency theorem is assumed to hold. There are constant returns to scale, zero pure profits, and no taxes on intermediate inputs. Second best optimal taxes are therefore levied on the household's supply of labour and demand for final consumption goods. Let t_L , t_I , and t_N denote tax rates on labour income and consumption of an energy-intensive respectively a non-energy-intensive consumption good, which are the final consumption goods in the model.⁴ Since there is no pure profit, one of the tax rates may without loss of generality be zero, cf. Munk (1978). Choosing $t_I = 0$, the tax instruments are t_L and t_N . The assumed preference structure, where leisure is weakly separable from the consumption aggregate, implies that the two consumption goods have the same degree of complementarity to leisure, whereby a second-best optimal tax rate on non-energy-intensive consumption is zero. Before we introduce the emission target, the tax solutions of the model follow from the tax revenue requirement,

$$t_L L + a \geq G, \quad (1)$$

where L denotes labour supply, a denotes a lump sum tax, and G is an exogenous income transfer to the representative consumer. Throughout the computations, the transfer is kept constant in real terms, i.e., $G_R = G/p_U$ is constant, where p_U is the ideal price index representing the true cost of living (the unit expenditure function). In the second-best solution, we assume that the lump sum tax is infeasible, such that $t_L L = G$. In other words, the second best tax rate is a function of the exogenous parameter G , i.e., $t_L^{SB}(G)$. Likewise, the first best tax solution follows from $a = G$, i.e., $a^{FB}(G)$.

Let e denote total carbon emissions from all production and consumption activities. When such emissions are regulated by a tax rate t_e , the tax system must fulfil the following two restrictions:⁵

⁴ For further details concerning the model, see Appendix A.

⁵ Equation (A4) in the appendix includes a tax on pure profits in addition to the labour income tax, the emission tax and the lump sum tax as shown in (2). Pure profits are zero in the unrestricted reference, but become positive

$$\begin{aligned} t_L L + a + t_e e &\geq G, \\ e &\leq E. \end{aligned} \tag{2}$$

E denotes the target level for total emissions. The second best tax solution now involves a labour income tax in combination with an emission tax, and the optimum tax rates are then functions of the two exogenous parameters G and E , $\{t_L^{SB}(G, E), t_e^{SB}(G, E)\}$. By analogy, the first best solution is denoted $\{a^{FB}(G, E), t_e^{FB}(G, E)\}$.

3. Welfare costs and excess burden

The total excess burden caused by distortionary taxation measures how much better off the representative consumer would have been if the same amount of tax revenue were collected by means of non-distortionary finance. Pauwels (1986) shows that the equivalent variation when going from a first best to a distortionary equilibrium (raising the same amount of revenue) represents a correct measure of the total excess burden. Let $(\mathbf{p}^{FB}, I^{FB})$ denote the first best consumer prices and non-labour income level, $V(\mathbf{p}, I)$ the indirect utility function, $U^{FB} = V(\mathbf{p}^{FB}, I^{FB})$ the first best utility level, and U^i the utility level in a state of the economy which is compared to the first best solution. Pauwels' equivalent variation measure of the excess burden may then be found from the following equation,

$$V(\mathbf{p}^{FB}, I^{FB} - EV) = U^i. \tag{3}$$

Let us first consider the situation without an emission target, where (1) is the only restriction on the choice of tax rates. Denoting the second best prices and non-labour income by $(\mathbf{p}^{SB}, I^{SB})$, we have that $U^{SB} = V(\mathbf{p}^{SB}, I^{SB})$. The total excess burden (EV) in (3) is determined by how much better off the consumer is in the first best than in the second best equilibrium. Thus, EV is positive whenever $U^{FB} > U^i = U^{SB}$. Since the consumer prices, non-labour income, and utility level are functions of the exogenous parameter G in (1), we introduce the shorthand notation $U^{FB}(G) = V(\mathbf{p}^{FB}(G), I^{FB}(G))$ and $U^{SB}(G) = V(\mathbf{p}^{SB}(G), I^{SB}(G))$, such that the equivalent variation in (3) also may be expressed as a function of G , $EV(G)$. If the government raised no taxes, $G = 0$, we would have that $U^{FB} = U^{SB}$, and $EV(0) = 0$. When the revenue requirement is positive, the welfare level in the second best economy becomes smaller than in the undistorted first best economy, such that $U^{FB} > U^{SB}$, and $EV(G) > 0$.

in the event that grandfathered quotas are used. For expositional simplicity, we have ignored that possibility here, since our focus primarily is on the implications of using a carbon tax to reduce emissions.

Our primary concern in this paper is how the welfare level and the welfare difference between a first and second best economy are affected by introducing a constraint on the total emission level. Since the optimal tax solutions then are derived from (2) instead of (1), consumer prices, non-labour income, and utility levels become functions of the two exogenous parameters G and E . Hence, we introduce the notation $U^{FB}(G,E) = V(\mathbf{p}^{FB}(G,E), I^{FB}(G,E))$ and $U^{SB}(G,E) = V(\mathbf{p}^{SB}(G,E), I^{SB}(G,E))$ for the first- and second best utility levels, respectively.⁶

We maintain the unrestricted first best solution as the reference from which all welfare costs are derived, and $U^{FB}(G)$ is the reference utility level. The *first best welfare cost* of reducing the emission level to E is denoted $EV^{FB}(G,E)$. It is implicitly defined from EV in (3) by setting $U^i = U^{FB}(G,E)$. By analogy, the *second best welfare cost* of reducing the emission level to E and raising revenue G is denoted $EV^{SB}(G,E)$, and is defined from (3) by setting $U^i = U^{SB}(G,E)$. The welfare cost of reducing emissions in the second best is then $EV^{SB}(G,E) - EV(G)$; i.e., the welfare cost of meeting both restrictions minus the welfare cost due to second best financing of the revenue requirement only.

We now arrive at a measure of the *welfare difference* between the first- and second best economies contingent upon the levels of G and E , viz., $EV^{SB}(G,E) - EV^{FB}(G,E)$. This measure extends Pauwels' excess burden to a situation where the tax policy pursues environmental goals in addition to the traditional role of raising revenue. When the restriction $e \leq E$ is non-binding in neither first nor second best, $EV^{SB}(G,E) - EV^{FB}(G,E)$ equals $EV(G)$.

Our main result is that the welfare difference between the first- and second best economies diminishes as the emission target E is reduced. The intuition is quite simple. Let e^{FB} and e^{SB} denote the unrestricted emission levels in the first- and second best economies, respectively. Since the first best economy is more efficient, the total activity level is higher, which normally implies that $e^{FB} > e^{SB}$. This is indeed the case in the numerical model studied in the next section. Starting from the point where the emission restriction starts to bind in the first best economy, $E = e^{FB}$, the first best utility level falls as E is reduced, while the second best utility level is maintained until E reaches e^{SB} . In the range from e^{FB} to e^{SB} the welfare difference thus is reduced with E . Reducing E further, we find that the welfare difference continues to fall. If the revenues from the emission tax are sufficient to fulfil the requirement, the tax solutions and utility levels in the first- and second best economies coincide, whereby (3) implies that the welfare difference is zero. This possibility arises for sufficiently low levels of G and E , see Figure 2 below.

⁶ The utility level is defined exclusive of environmental quality; we only study utility from private consumption

4. Numerical results

Compared to the first best economy, a labour income tax rate of 40% reduces the labour input by 13,2% and implies a welfare loss or an excess burden $EV(G)$ of 116.5 billion dollars. This amounts to approximately 2.5% of the full endowment income in the second-best benchmark equilibrium. Total emissions in the first and second-best equilibria are 1639 respectively 1424 million tons.⁷

Impose now a restriction on total emissions, $e \leq E$, where E is stipulated at 1639 million tons, and consider the effects from reducing E in steps. For each step we compute the welfare cost in terms of the equivalent variation from the unrestricted first best equilibrium. See Figure 1. The constraint binds immediately in the first best, while it remains slack in second best until E attains the benchmark level of 1424. At $E = 1424$, the emission tax in the first best causes a reduction of the utility from leisure and consumption goods. The second-best equilibrium is unaffected at this emission level, i.e., $EV^{FB}(G,E) > 0$ while $EV^{SB}(G,E) = EV(G)$. By reducing the cap further, both equilibria are affected. Figure 1 shows the effects on welfare costs of reducing the emission level from the initial unrestricted first-best level $e = 1639$ to $e = 900$.

As a digression, consider grandfathered quotas. This instrument is no different than using taxes in the first-best economy. In the second best, however, it implies an extra welfare cost, measured as the equivalent variation from (3). In Figure 1, the equivalent variation of grandfathered quotas is denoted $EV^{SB}(G,E)_{grandfathered}$.

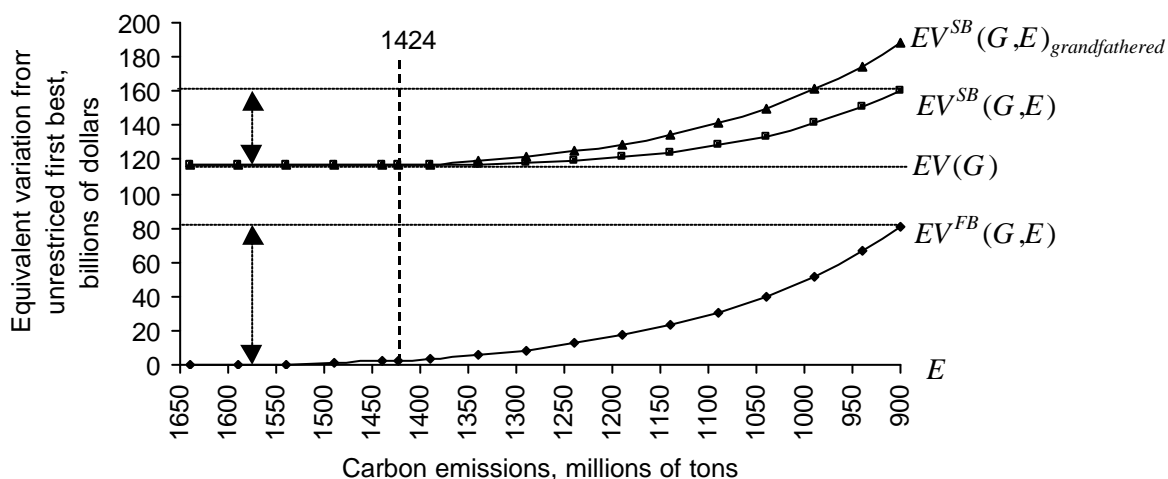


Figure 1. Welfare costs and welfare difference when reducing emissions

goods and leisure.

⁷ For each activity, the model employs a fixed coefficient of carbon content. Thus, higher activity levels come with higher total emissions.

The first-best welfare cost of reaching the emission target $E = 900$ is 80.4 billion dollars, indicated by the lowermost arrow in Figure 1. The welfare cost of obtaining the *same emission target* in the second-best version of the model, however, is the differential cost of 43.8 billion dollars, $EV^{SB}(G,E) - EV(G) = 160.3 - 116.5$, as indicated by the uppermost arrow, and not the entire 160.3. Thus, for this emission level the welfare cost of regulating the second-best economy amounts to only a little more than half the cost of regulating in the first-best setting.

The welfare difference $EV^{SB}(G,E) - EV^{FB}(G,E)$ can be read from Figure 1 as the vertical distance between the curves $EV^{SB}(G,E)$ and $EV^{FB}(G,E)$. The isolated effect on economic efficiency of a labour income tax of 40% is captured by the initial excess burden $EV(G)$ of 116.5 billion dollars. As a binding emission target E constrains the use of polluting inputs, the welfare difference diminishes. At $E = 900$, the welfare difference is reduced to 79.8 billion dollars. This is when the revenue-recycling effect – using the carbon tax revenue to cut the labour income tax rate – is exploited. If a carbon revenue is not used to reduce pre-existing distortionary taxes, however, as is the case when using grandfathered quotas, the welfare difference between the first best and the $EV^{SB}(G,E)_{grandfathered}$ is 107.7 billion dollars. Thus, regulating emissions by means of grandfathered quotas inflicts an extra welfare cost compared to a regulation with emission tax or auctioned quotas. At $E = 900$, this additional welfare cost amounts to 27.9 billion dollars, or almost 65% over and above the welfare cost of the carbon tax.

Full efficiency-convergence

The insight provided by the above computations may become even more transparent if we modify one parameter of the model, namely the level of tax revenue. Assume that the labour tax rate is 20% and not 40%, and that the governmental revenue requirement is reduced accordingly. Let us redo the experiment of reducing the emission cap from its maximum, which still is 1639. Because of the reduced tax rate, the distortion from taxation in second best is smaller, and the excess burden of the unregulated second-best economy, $EV(G)$, is reduced from 116.5 to 21.4 billion dollars. The overall activity level in second best is now larger and results in total emissions of 1551 million tons.

Figure 2 displays the welfare difference $EV^{SB}(G,E) - EV^{FB}(G,E)$ as a function of the emission target. At $E = 658$ million tons, the emission tax is sufficient to generate the governmental revenue requirement. Therefore, the reform of replacing the labour tax with an environmental tax coincides with the first-best solution to environmental regulation at this

particular level of G and E .⁸ The two model economies are equally efficient and provide the same welfare. Thus, the initial welfare difference between the first- and second best economies of 21.4 billion dollars is not only reduced, it disappears completely if the emission level is reduced to $E = 658$.

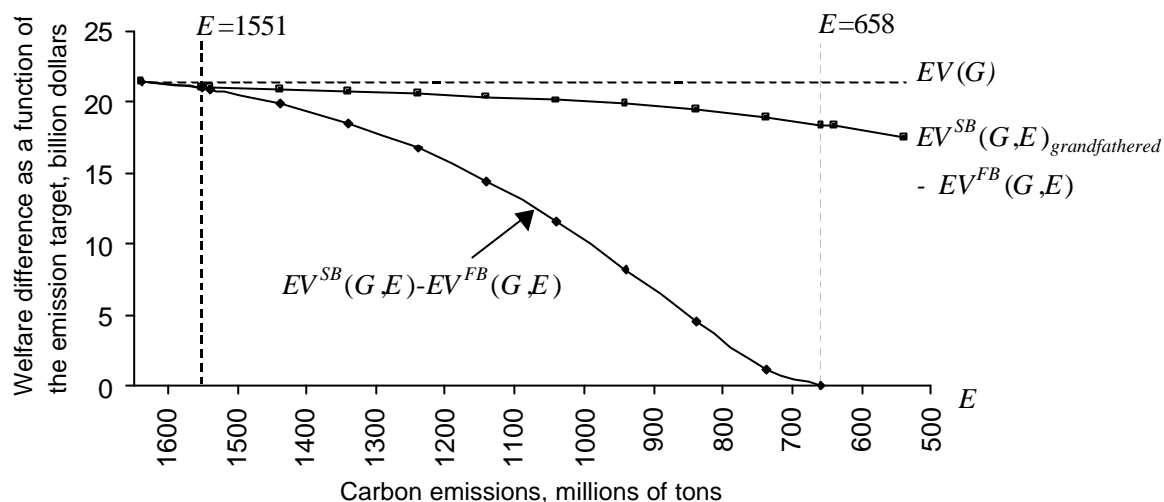


Figure 2. Welfare difference as a function of the emission target E .

Also here, we have included the welfare difference from using a grandfathered quota instead of a carbon tax. We observe that grandfathered quotas provide only a small efficiency-convergence, which is because this regulatory instrument does not exploit the benefits of revenue recycling. In stead of being reduced in the example of Figure 2, the labour income tax rate increases from the initial rate of 20% to 22% as the carbon emissions are reduced from 1551 to 658 million tons.⁹

⁸ This is essentially Sandmo's observation, see Sandmo (1995).

⁹ Actually, it is misleading to speak of grandfathered quotas as a second-best instrument. This instrument is strictly dominated by either a carbon tax or auctioned quotas. A solution obtained by a combination of a labour tax and grandfathered quotas thus belongs to the class of third best or less-than-second-best solutions.

5. Concluding comments

This paper has investigated the costs of imposing emission restrictions in economies with and without pre-existing distortive taxes. We have found that the efficiency difference between these economies diminishes as a consequence of such an emission restriction. The revenue generated by the emission tax replaces the initial taxes of these economies, thus making their tax bases more similar. A more ambitious emission target implies that a higher fraction of total tax revenues will stem from emission taxes. Thus, the initial difference between the distorted and non-distorted economy is reduced.

Sandmo (1995) and Oates (1995) made similar points. It should be noted, however, that their setting was that of optimal Pigouvian taxation, i.e., the correction of an external cost. Our analysis considers neither external costs nor benefits from an improved environment. It solely focuses on the cost of complying with the regulation, and it is the introduction of a common emission level that causes efficiency convergence between the economies. This result is impossible to read from GP's analyses. In fact, one might easily get the opposite idea. In this respect, our paper complements their results, and hopefully contributes to a more complete understanding of the differences between the first and the second best.

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Appendix A. The model of Parry et.al. (1999)

There are six intermediate goods; coal (F_C), petroleum (F_P), natural gas (F_N), electricity (E), other energy-intensive intermediate goods (I), and non-energy-intensive intermediate goods (N). Further, there are two final consumption goods: an energy-intensive good (C_I), and a non-energy-intensive good (C_N). Production of intermediate and final goods are described by constant returns nested CES production functions, and each producer takes input and output prices as given. Labour is input to the production of the six intermediate goods, while the two final goods are aggregates of intermediate inputs only.

There is a representative consumer with preferences over leisure (l) and the two final goods, expressed by the utility function

$$U(l, f(C_I, C_N)). \quad (A1)$$

σ^h and σ^f denote the elasticities of substitution between l and $f(\cdot)$, respectively C_I and C_N . The consumer maximises U subject to the budget constraint

$$p_{C_I} C_I + p_{C_N} C_N = p_L L(1 - t_L) + \mathbf{p}(1 - t_R) + G - a, \quad (A2)$$

where $L = \bar{L} - l$ is labour supply, t_L and t_R are tax rates on labour and rent income respectively, G is transfer income, which throughout the analyses is kept constant in real terms, and a is a lump sum tax. In the reference equilibrium (without a carbon restrictions), there is no pure profit, $\pi = 0$. When, however, the government uses grandfathered quotas to restrict emissions, π represents the quota rents that accrue to the private sector. It is assumed that $t_R = t_L$.

Carbon emissions stem from the use of coal, natural gas, and petroleum. Each of these has a fixed carbon emission coefficient β_i , $i = F_C, F_N, F_P$, such that total carbon emissions (e) becomes

$$e = \mathbf{b}_{F_C} F_C + \mathbf{b}_{F_N} F_N + \mathbf{b}_{F_P} F_P. \quad (A3)$$

The government's budget constraint equalises total tax revenues (REV) with the lump sum transfer (G),

$$REV = a + t_L L + t_R \mathbf{p} + t_e e = G. \quad (A4)$$

Under a carbon tax (t_e), $\pi = 0$, while under a grandfathered quota, $t_e = 0$. In first-best tax solutions, the lump sum tax a is used, while t_L is zero. The opposite is the case in second-best solutions, where we assume that lump sum financing cannot be used, such that the tax revenue requirement must be met by a combination of t_L , t_R , and t_e .

The benchmark data set is collected from Parry et al's Table 1, which represents an approximation to the US economy in 1995. The data and the elasticities of substitution in the various CES aggregates are restated an appendix which is available from the authors.