DOUBLE DIVIDEND WITH TRADE DISTORTIONS:
ANALYTICAL RESULTS AND EVIDENCE FROM CHILE

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Working Paper 99-WP 225
September1999

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Abstract

The double-dividend debate evolves around the possibility (or not) of substituting environmental taxes for more distortionary taxes to reduce both pollution degradation and/or damages (the first dividend) and the excess burden of existing taxes (the second dividend), without eroding tax revenues. This paper contributes to the double dividend debate with a formal analysis and some numerical evidence emphasizing trade and environmental distortions. The substitution of environmental taxes for trade distortions has been neglected in the double-dividend debate, which has centered on labor market distortions. Conditions for the existence of a double dividend are derived for different characterizations of preferences and policy menus. We empirically explore the trade/environment double dividend with an applied general equilibrium model of the Chilean economy. The model includes many distortions and a vector of six air pollution effluents, their health incidences and associated damages, which are assumed nonseparable from market goods. Findings suggest solid evidence of a trade/environment double dividend in the case of Chile. Swapping environmental taxes for trade distortions improves welfare. The swap would even pay for itself under the assumption of separable pollution damages from market-good consumption.

Key words: Double dividend, trade and environment, piecemeal reform, policy coordination, Chile.
JEL classification: F13, Q28, and H21.

DOUBLE DIVIDEND WITH TRADE DISTORTIONS: ANALYTICAL RESULTS AND EVIDENCE FROM CHILE

The double-dividend debate revolves around the possibility, or not, of substituting environmental taxes for more distortionary taxes to reduce both pollution degradation and/or damages (the first dividend) and dead-weight losses arising from the excess burden of existing taxes (the second dividend), without eroding tax revenues. The literature usually attributes the original idea to Terkla, although there are earlier papers, which consider Pigouvian taxes as sources of tax revenues (e.g., Ng). Recent contributions include Bovenberg and Goulder, Espinosa, Goulder and others. At the heart of the debate are the second-best effects of the introduction of the new taxes. While it is intuitive, the double-dividend conjecture has been controversial and difficult to establish because the introduction of a new tax instrument can exacerbate existing distortions via cross-price effects in consumption or production and hence can reduce welfare (Oates).[1]

Our paper contributes to the double-dividend debate with a formal analysis and numerical evidence emphasizing the substitution of environmental taxes for trade distortions. The substitution of environmental taxes for trade distortions has been neglected in the double-dividend debate. The latter had been focusing mostly on labor market distortions and corporate taxation, although the second-best foundation of the double dividend controversy applies to all distortionary taxes. Our investigation is primarily, but not uniquely, relevant in the context of developing economies, which are often ridden through with trade and environmental distortions, and for which tax revenue considerations are essential. Although border tariffs (trade taxes) have been declining historically with the successive GATT rounds, the Uruguay Round Agreement actually implies increases in many trade taxes, with the ongoing tariffication of nontariff trade barriers and the so-called tariff-rate quotas, or TRQs. This tariffication will increase the importance of tariffs as revenue sources for many economies. Simultaneously, many developing economies are reaching their environmental transition. Their income levels have risen and induced environmental externalities. Environmental taxes have not been introduced yet or, at best, are below the marginal damage of pollution associated with economic growth.

We derive conditions for the existence of a double dividend for several of its definitions. Goulder (1995), Espinosa, and Oates review the different meanings and forms of the double-dividend claims and investigations. One potential taxonomy arises from different understandings of the environmental dividend. Many empirical investigations of the double dividend implicitly abstract away from the consumer's valuation of the reduction of pollution. This seemingly innocuous abstraction imposes a lot of structure on preferences and means that either pollution reduction does not enter the utility of the consumer or that pollution is strongly separable from all private-good consumption. These latter investigations focus on the reduction, or the increase, in excess burden induced by that reduction in pollution resulting from the tax substitution (e.g., Bovenberg and Goulder in their numerical model). A few empirical papers have explicitly explored the valuation of the reduction in pollution, which corresponds more closely to the underlying theory (see, for example, Espinosa).

We explore several cases with different characterizations of preferences. We use a dual approach to trade à la Dixit-Norman. This framework has been used to analyze trade and environment linkages in small, open and distorted economies (Copeland; Beghin et al. [1997]) and to analyze revenue-enhancing tariff reforms (Falvey). We basically combine these two types of analyses. We consider trade and environmental tax reforms, for which tax revenues are nondecreasing.

We find two sets of analytical results on the existence of double dividend involving trade distortions. We first consider general preferences, allowing for interaction between market demand and the pollution externalities (i.e., Hicksian demands respond to pollution). In the latter case, a trade/environment double dividend exists as long as the initial structure of tariffs satisfies a mild requirement. For policy menus that proportionally reduce relative trade and environmental distortions, a double dividend still exists as soon as the distortionary impact of tariffs on the marginal cost of living is bigger than their distortionary impact on the marginal damage of one of the pollution emissions. This condition rules out the possibility that the feedback of the tax reform on tax revenue, through the decrease in pollution including the latter's feedback in utility, is negative.

Still, with unrestricted preferences, a double dividend also exists if, pollution damages increase with trade liberalization. The latter condition is consistent with stylized results coming from economywide models (Perroni and Wigle, Lee and Roland-Holst; Beghin et al. [1995]; and

Dessus and Bussolo). Finally, we establish existence results for some specific types of tax reforms and initial tax structures.

In the case of separable utility (i.e., Hicksian demands independent of pollution), the existence of a double dividend for the same specific policy menus does not require any assumptions, beyond the usual assumptions on well-behaved technology and preferences, and a mild requirement on the initial tariff structure.

Next, we empirically explore the trade/environment double dividend with an applied general equilibrium model of the Chilean economy. We find solid evidence of a trade/environment double dividend in the case of Chile. However, the welfare effects are moderate. We had previously analyzed trade and environment linkages in the Chilean economy and found strong, but cluttered, evidence of a double dividend (Beghin et al. [in press]). The former analysis relied on a dynamic model and had built-in terms-of-trade effects and productivity gains, which resulted in loss of transparency. Here, we use a static version of this model and we abstract from terms of trade. We find that the (trade/environment) double-dividend reforms have a negative cost in terms of allocative efficiency. They pay for themselves while ignoring the welfare gains from reduced health damages associated with pollution. In addition, the health damages reductions appear significant. Further, we find no evidence that the new environmental tax exacerbates existing tax distortions. This was a central issue in several empirical papers (e.g., Bovenberg and de Mooij). We surmise that the exacerbation of distortions is more likely to occur in stylized models that have a small disaggregation of factors and sectors and a dichotomic characterization of the few goods as being either clean or "dirty."

The Basic Model

Following Falvey, Dixit and Norman, and Copeland, we use the dual approach to a perfectly competitive and open distorted economy. Two types of distortions are present. Trade is distorted by border taxes. We rule out the trivial case in which the trade tax rates are uniform. Hence, we have in mind a situation with an heterogeneous trade tax structure, which creates significant dead-weight losses and positive revenues. Pollution emissions produced by various industries aggregate into a vector of public bad for the representative consumer. Marginal damage of pollution is the

marginal impact of pollution on expenditure to hold utility constant. Effluent taxes depart from their optimal level, which include the case where they do not exist initially. This policy departure is the second distortion. This second distortion is consistent with a fast-growing developing economy in which the policy response is inadequate and lags behind private agents' valuation of the environment.

Under perfectly competitive markets, production decisions are modeled by a revenue or GDP function R, with $R(P + \tau, \varepsilon, v) = \max_{(x, z)}\{(P + \tau)'x - \varepsilon z \mid (x, z)$ feasible given inputs $v\}$; where P is the vector of n exogenous world prices of n goods x; τ is the vector of trade taxes on these goods; ε represents the (kx1) vector of taxes on k effluent types z. The revenue function is homogeneous degree one in prices and taxes. All prices P can be normalized to one by appropriate scaling of units and τ is equivalently the vector of *ad valorem* or specific tariffs. One of the goods can be chosen as a numeraire to impose homogeneity. R exhibits all the desired properties. The usual envelope theorem results hold. We have $R_p = x$ and $R_\varepsilon = -z$. Matrix R_{pp} is the Hessian of price responses of the output vector x; and $R_{\varepsilon\varepsilon}$ is minus the response of production pollution to effluent taxes; $R_{\varepsilon p}$ = minus the cross-price response of production pollution to output prices; $R_{\varepsilon p} = R_{p\varepsilon}'$ and it is the response of output to the effluent tax. $R_{\varepsilon\varepsilon}$ is positive by convexity of R in prices and taxes.

Labor-market distortions are not the focus of our investigation, but given the importance of these distortions in previous papers, we briefly explain how we model the labor market here. In this dual framework, we can treat labor two ways. Either labor is considered an endowment in fixed supply (an element of v), or it can be treated as an internationally mobile factor with a given world price and then it can be treated just as a commodity. In the latter case, excess demand clears on the world market at the international wage level. We do not consider the intermediate case of labor as a nontraded factor with a price-responsive supply.

The economy has a representative consumer with expenditure function E, with

$E(P + \tau, z_0, U_0) = \min_{(c)}\{(P + \tau)'c \mid U \geq U_0, z \geq z_0\}$, where c represents the consumption vector of n goods, and U denotes utility. A similar set of derivatives can be obtained from the expenditure E, starting with $E_p = c$. Another derivative, E_z, represents the vector of marginal damage of pollution on utility, or the necessary increase in expenditure to maintain U constant when pollution emissions, z, increase. Marginal damage is positive. The final derivative of interest is the inverse of the marginal utility of income, E_U, which is positive as well. Derivatives E_U and

E_z have derivatives with respect to the consumption price vector (E_{pU} and E_{pz}). Under the separability assumption, the latter set of derivatives E_{pz} is set equal to zero. Last, we have E_{pp}, the Hessian of price responses of the consumption vector c.

The equilibrium of the economy is described and fully characterized by three fundamental equations (a balance of trade constraint, the definition of pollution, and tax revenues from trade and pollution taxes)[2]

(1) $$P' (E_p - R_p) = 0,$$

(2) $$z = -R_\varepsilon, \text{ and}$$

(3) $$T = \tau'(E_p - R_p) - \varepsilon 'R_\varepsilon.$$

Foreign and domestic specific commodities are perfect substitutes and exhibit the same effluent rate. We define the trade/environment double dividend as a reform of taxes τ and ε, which reduces both trade and environmental distortions, and which would induce an increase in utility, u, ($dU>0$), a decrease in pollution, z, or its damages ($dz<0$ or $E_z^{*}{}'dz <0$), without a deterioration of tax revenues, T, ($dT \geq 0$).

We differentiate system (1)-(3) and obtain the following system of equations with endogenous variables dU, $-dz$, and dT, and exogenous shocks $d\tau$ and $d\varepsilon$. We look at improvements of the environment, $-dz$, rather than its degradation, dz, because of its convenience in the application of the theorem of the alternative used to establish our results. The differentiation yields:

(4) $$E_u^{*}dU - E_z^{*} (-dz) = (P'R_{p\varepsilon}) d\varepsilon - P'(E_{pp} - R_{pp}) d\tau,$$

with $E_u^{*}= E_U - \tau'E_{pU} = P'E_{pU}> 0$ for stability, and $E_z^{*}= E_z - \tau'E_{pz} = P'E_{pz} > 0$;

(5) $$-dz = R_{\varepsilon\varepsilon} d\varepsilon + R_{\varepsilon p} d\tau, \text{ and}$$

(6) $$-E_u dU + E_z (-dz) + dT = -R_\varepsilon d\varepsilon + (E_p - R_p) d\tau.$$

Equations (4)-(6) make use of homogeneity results $(P + \tau)'E_{pp} = 0$, $(P + \tau)' R_{pp} + \varepsilon' R_{\varepsilon p} = 0$, and $(P + \tau)' R_{p\varepsilon} + \varepsilon' R_{\varepsilon\varepsilon} = 0$, and of the fact that $(P + \tau)' (E_p - R_p) = \tau' (E_p - R_p)$ since $P' (E_p - R_p) = 0$ (balance of trade).

Note that equation (5) could be pre-multiplied by a vector of distortions $(E_z^{*} - \varepsilon)'$ or by $E_z^{*}{}'$ to express the reduction in the environmental distortion. These could lead to two alternative definitions of the environmental dividend ($-E_z^{*}{}'dz$, and $-(E_z^{*} - \varepsilon)' dz$).

Following Turunen-Red and Woodland, and Falvey, we establish the existence of a double dividend with an application of the theorem of the alternative (Mangasarian). Several forms of the theorem exist, and we use the most general one allowing for three variables of interest: Two positive (dU), (−dz), and one nonnegative (dT).[3] The theorem of the alternative states that either system (4)-(6) as a solution with dU positive, (−dz) positive and dT nonnegative, or its alternative, described below, has a solution x, but never both.

Assuming that the environmental dividend is defined as (−dz), the alternative system is

(7) $$E_U^* x_1 - E_U x_2 > 0,$$

(8) $$-E_z^* x_1 + E_z x_2 + x_3 \geq 0,$$

(9) $$x_2 \geq 0,$$

(10) $$-x_1 P'(E_{pp} - R_{pp}) + x_2 (E_p - R_p) + x_3 R_{\varepsilon p} = 0, \text{ and}$$

(11) $$x_1 P'R_{p\varepsilon} - x_2 R_\varepsilon + x_3 R_{\varepsilon\varepsilon} = 0,$$

with x_1 and x_2 being scalars and x_3 being a (kx1) vector. Slight modifications to equations (8), (10), and (11) occur if the alternative characterization of the environmental dividend is used $(-(E_z^* -\varepsilon)'dz)$ (a reduction of the environmental distortion with the tax, ε, being smaller than the marginal damage, E_z^*). Because of homogeneity in prices and taxes of R and homogeneity in prices of E, equations (10) and (11), when post-multiplied by $P + \tau$ and ε respectively, and then summed up, lead to the solution $x_2 = 0$.

Hence the alternative system becomes:

(7') $$x_1 > 0;$$

(8') $$x_3/x_1 \geq E_z^* > 0$$

(9') $$x_2 = 0,$$

(10') $$x_1 P' (R_{pp} - E_{pp}) + x_3' R_{\varepsilon p} = 0, \text{ and}$$

(11') $$x_1 P'R_{p\varepsilon} + x_3' R_{\varepsilon\varepsilon} = 0.$$

Equations (10') and (11') are then combined to construct a quadratic form. Post-multiply (11') by Px_1 and (12') by x_3, and them sum them to obtain:

(12) $$x_1 P'R_{pp} Px_1 - x_1P' E_{pp}P x_1 + x_3 R_{\varepsilon p} P x_1 + x_1 P' R_{p\varepsilon} x_3 + x_3' R_{\varepsilon\varepsilon} x_3 = 0.$$

We are insured that (12) is a sum of two nonnegative terms, since R is convex in prices and taxes and E is concave in prices.

The application of the theorem of the alternative relies on identifying conditions under which the alternative system (7')-(11') does not have a solution to prove the existence of a solution for the primary system. For example, equation (12) will be strictly positive if the initial tariff structure leads to $-P'E_{pp}P = \tau' E_{pp}P > 0$, the latter being always nonnegative for all tariff structure. We can state our first general result as follows:

Result 1

A double dividend (dU > 0; −dz > 0; dT ≥ 0) exits for piecemeal tax reforms swapping effluent taxes for trade taxes (dτ, dε), under the assumptions of a competitive open distorted and polluted economy as described by system (1)-(3),

(i) if the initial tariff structure τ is such that (τ'E$_{pp}$P = −P'E$_{PP}$P) is strictly positive.

The proof is immediate. Substitute a strictly positive number for -P'E$_{pp}$P in (12) to get a contradiction between (12), and (7') and (9').

Although general and useful in the sense of not requiring much structure, this result provides little guidance for designing a policy menu leading to a double dividend. Next, we derive further results for specific reform menus. We consider the class of piecemeal tax reforms that bring domestic relative tariffs toward uniformity by reducing them by a factor $(1/(1+k_\tau))$, that is $(d\tau=Pk_\tau)$, and that decrease relative environmental distortions by a factor $1/(1+k_\varepsilon)$, i.e., $(d\varepsilon = k_\varepsilon E_z^*)$. The intuition of this menu is that the tariff reform brings relative domestic prices $\{(P_i+(\tau_i/(1+k_\tau))) /((P_j+(\tau_j/(1+k_\tau))))\}$ closer to relative world prices (P_i/P_j) and hence reduces trade distortions. Similarly but less obviously, the increase in the environmental tax brings the ratio $([P_i+(\tau_i/(1+k_\tau))]/[E_{zj}^*+((\varepsilon_j−E_{zj}^*)/(1+k_\varepsilon))]$ closer to the relative shadow price (P_i/E_{zj}^*) for all i and j.

This type of reform is reminiscent of earlier results established by Hatta, Turunen-Red and Woodland, Copeland, Beghin and Karp, and Beghin et al. (1997), which show that coordinated reforms involving proportional reductions of all distortions improves welfare. Here, in addition, we want to establish conditions for existence of a double dividend in the sense that, beyond the welfare improvement, pollution damages decrease while tax revenues are not eroded (a triple requirement).

We substitute $d\tau = Pk_\tau$ and $d\varepsilon = k_\varepsilon E_z^*$ in the primary system (4)-(6) to obtain:

(13) $\qquad E_u^* \, dU − E_z^* \, (−dz) − (P' R_{p\varepsilon}) k_\varepsilon E_z^* − P'(E_{pp} − R_{pp}) Pk_\tau = 0,$

(14) $\qquad -E_z^{*\prime}dz - E_z^{*\prime}R_{\varepsilon\varepsilon}\,k_\varepsilon E_z^{*} - E_z^{*\prime}\,R_{\varepsilon p}\,Pk_\tau = 0,$

(15) $-E_u\,dU + E_z'(-dz) + dT + R_\varepsilon\,k_\varepsilon E_z^{*} - (E_p - R_p)\,Pk_\tau = 0,$ with variables dU, −dz, dT, k_ε, and k_τ.

The double dividend is defined as $dU > 0$, $-E_z^{*\prime}dz > 0$, and $dT \geq 0$.

The corresponding alternative system is:

(16) $\qquad\qquad E_U^{*}\,x_1 - E_U\,x_2 > 0,$

(17) $\qquad\qquad -E_z^{*}\,x_1 + E_z\,x_2 + E_z^{*}\,x_3 \geq 0,$

(18) $\qquad\qquad x_2 \geq 0,$

(19) $\qquad -x_1\,P'(E_{pp} - R_{pp}) + x_2\,(E_p - R_p) + x_3\,E_z^{*\prime}\,R_{\varepsilon p} = 0,$ and

(20) $\qquad x_1\,P'R_{p\varepsilon} - x_2\,R_\varepsilon + x_3\,E_z^{*\prime}R_{\varepsilon\varepsilon} = 0,$ with x_1, x_2 and x_3 being scalars.

From (18) and (16) we have x_2 semi-positive and x_1 strictly positive, and $x_2/x_1 < E_U^{*}/E_U$. Using the latter inequality and (17) we have the following inequality: $x_3/x_1 > 1 - (E_{zj}/E_{zj}^{*\prime})$ (E_U^{*}/E_U), for all element j of E_z^{*}. Post-multiplying (19) by (P/x_1) and (20) by $E_z^{*}(x_3/x^2_1)$ and summing them yield:

(21) $-P'E_{pp}\,P + P'R_{pp}\,P + (x_3/x_1)E_z^{*\prime}R_{\varepsilon p}\,P + P'R_{p\varepsilon}\,E_z^{*}\,(x_3/x_1) + (x_3/x_1)\,E_z^{*\prime}R_{\varepsilon\varepsilon}\,E_z^{*\prime}(x_3/x_1) - (x_2/x_1)$ $R_\varepsilon E_z^{*\prime}\,(x_3/x_1) = 0.$

The latter expression is the sum of two nonnegative quadratic forms and $(x_2/x_1)z\,E_z^{*}(x_3/x_1)$, which is not restricted in sign. As soon as $-P'E_{pp}P$ in (21) is strictly positive, (x_3/x_1) must be negative for a solution to the alternative to exist.

Further equation (19), after being post-multiplied by (P/x_1), implies that $((x_3/x_1)\,E_z^{*\prime}R_{\varepsilon p}P) < 0$ if $-P'E_{pp}\,P > 0$. Recall that $E_z^{*}\,(\partial z/\partial P)\,P = -E_z^{*\prime}R_{\varepsilon p}\,P$. Hence the existence of a solution to the alternative, conditioned on $-P'E_{pp}P > 0$, requires that pollution on "average," or its damage contracts with trade liberalization. How strong is this condition $(E_z^{*\prime}\partial z/\partial p\,P < 0)$? Our previous work on Chile, Costa Rica, and Mexico (Beghin et al. [in press], Dessus and Bussolo, and Beghin et al. [1995]) as well as other papers analyzing Asian countries (e.g., Lee and Roland-Holst), suggest that emissions do expand for most pollution types with trade liberalization. The aggregate scale effect overwhelms effects from specialization or from input mix changes when domestic prices are being realigned with world prices. In general the output expansion induces more pollution for most pollutants even though the country does not necessarily specialize in "dirtier" activities. In addition, trade liberalization often lowers the cost of energy and, as a result, increases the energy

intensity of output. We revisit again the evidence of pollution expansion under trade liberalization in the empirical section.

In addition and still conditioned on $-P'E_{pp}P>0$, the requirement that $(x3/x1)$ be negative, means that $(E_{zj}/E_u - E_{zj}^*/E_u^*)$ be positive for all pollution types j represented by vector z. This requirement is equivalent to having the distortionary effect of tariffs on the marginal cost of living represented by $(\tau' E_{pu}/E_u^*)$ be smaller than their impact on the marginal damage of pollution represented by $(\tau' E_{pzj}/E_{zj}^*)$ for all pollution z_j.[4] The intuition of this requirement is that the reform induces a reduction in pollution, which in turn has a negative effect on tax revenues despite the higher utility of lower pollution and its effect on tax revenues, that is $dT/dz=E_z-E_z^* (E_u /E_u^*)>0$. Meeting this condition is an empirical question that depends on the initial tariff structure τ and on the various weights $(\partial c_i/\partial u, \partial c_i/\partial z)$. The tariffs can be positive or negative. Mild restrictions on preferences are sufficient to show that $(E_{zj}/E_u - E_{zj}^*/E_u^*) \leq 0$ and that no solution exists to the alternative system (16)-(20).

For example, expenditure functions of the form $E (P + \tau, z, U) = E (P + \tau, z_{(-j)}, \Gamma (z_j , U))$, for some pollution z_j, imply that the alternative has no solution.[5] This added structure on preferences is moderate. It requires that the pair (U, z_j) be separable from the prices $P+ \tau$. This added structure does not put restrictions on preferences for market goods, given z_j. Nor does it impose structure between market goods and the other pollution types $z_{(-j)}$. We are now ready to formalize the conditions under which no solution exists for the alternative system (16)-(20).

Result 2

Under the assumptions of a small open and distorted economy described by system (4)-(6), a double dividend ($dU > 0, -E_z^{*'}dz > 0, dT\geq 0$) exists for the class of piecemeal tax reforms that bring domestic relative tariffs toward uniformity by reducing them by a factor $(1/(1+k_\tau)$, that is ($d\tau = Pk_\tau$), and that decrease relative environmental distortions by a factor $1/(1+ k_\varepsilon)$, i.e., ($_d\varepsilon = k_\varepsilon E_z^*$),

(i)   if the initial tariff structure τ is such that ($\tau'E_{pp}P =- P'E_{PP}P$) is strictly positive, and

(ii)   if the impact of trade distortions on the marginal cost of living is not smaller than their impact on the marginal damage of pollution zj, ($\tau' E_{pu}/E_u^* \geq (\tau' E_{pzj}/E_{zj}^*)$ for some j, or (alternative to (ii))

(iii)   if pollution damages expand with trade liberalization, $E_z^{*'}(\partial z/\partial P) P>0$.

We also have the following third result.

Result 3

Under the assumptions of a small open and distorted economy described by system (4)-(6), a double dividend (dU >0, −E_z^{*}'dz >0, dT ≥ 0) exists for the class of piecemeal tax reforms that bring domestic relative tariffs toward uniformity by reducing them by a factor (1/(1+k_τ), that is (dτ = Pk_τ), and that decrease relative environmental distortions by a factor 1/(1+ k_ε), i.e.,(dε = $k_\varepsilon E_z^{*}$),

(i)if the initial tariff structure τ is such that (τ'E_{pp}P = −P'E_{PP}P) is strictly positive, and

(ii)if preferences are consistent with the expenditure function E(P+τ, z, U)= E(P+τ, $z_{(-j)}$, Γ(z_j,U)) for some j.

Obvious additional corollary results exist for the special case of ε =0 in the previous results. This means that prior to the tax swap reform, environmental taxes were not used. This would be the case of a developing economy, which has not yet introduced environmental policy prior to the reform.

Double Dividend without Marginal Damage of Pollution

Many investigations of the double dividend assume away the valuation of the environmental improvement induced by the tax swap by assuming that the environmental benefit can be measured separately from the reduction in excess burden or would just be additive to the reductions in excess burden (see Goulder, and Espinosa for excellent reviews of these papers). As mentioned in the introduction, this imposes a lot of structure on preferences. The focus on the potential reduction of dead-weight losses from taxes would be sufficient to establish that a double dividend exists if the welfare cost of the tax swap is negative (a decrease in excess burden). Because of its importance, we analyze this restricted case. Result 1 is virtually unchanged by the added structure, since the double dividend is established directly for a pollution reduction. The other results pertaining to the specific policy menus are affected since they were established in terms of pollution damages. We consider the reductions in relative trade distortions (dτ = Pk_τ), and proportional increases in environmental taxes (dε = k_ε ε).

We assume that Hicksian demands (E_p) are independent of pollution levels, i.e., E_{pz}= 0. Several feedback effects are lost doing so. First, there are no utility gains from decreasing the pollution. tax revenues do not decrease because of pollution reductions, but are handicapped by the smaller increase in utility given . The decrease in pollution is unchanged. System (4)-(6) becomes:

(22) $\qquad E_u^{\,*}\, dU = (\, P'R_{p\varepsilon})\, k_\varepsilon\, \varepsilon - P'(E_{pp}-R_{pp})\, Pk_\tau,$

with $E_u^{\,*} = E_U - \tau'E_{pU} = P'E_{pU} > 0$ for stability; and $E_z^{\,*} = P'\,E_{pz} = 0 = (P + \tau)'E_{pz}$ by assumption.

(23) $\qquad -dz = R_{\varepsilon\varepsilon}\, k_\varepsilon\, \varepsilon + R_{\varepsilon p}\, Pk_\tau,$ or $- \varepsilon'dz = \varepsilon'R_{\varepsilon\varepsilon}\, k_\varepsilon\, \varepsilon + \varepsilon'R_{\varepsilon p}\, Pk_\tau,$ and

(24) $\qquad -E_u\, dU + dT = -R_\varepsilon\, k_\varepsilon\, \varepsilon + (E_p - R_p)\, Pk_\tau.$

The alternative system becomes:

(25) $\qquad\qquad E_U^{\,*}\, x_1 - E_U\, x_2 > 0,$

(26) $\qquad\qquad\qquad x_3\, \varepsilon \geq 0 ,$

(27) $\qquad\qquad\qquad x_2 \geq 0,$

(28) $\qquad\qquad -x_1\, P'(E_{pp}-R_{pp})\, P + x_3\, \varepsilon'\, R_{\varepsilon p}\, P = 0,$ and

(29) $\qquad\qquad x_1\, P'R_{p\varepsilon}\, \varepsilon - x_2\, R_\varepsilon\, \varepsilon + x3\, \varepsilon\, 'R_{\varepsilon\varepsilon}\, \varepsilon = 0.$

Pre-multiplying (28) by x_1 and (29) by x_3, and summing them, yield

(30) $-x_1\, P'E_{pp}\, Px_1 + x_1 P'R_{pp}\, Px_1 + x_3\, \varepsilon'\, R_{\varepsilon p}\, Px_1 + x_1\, P'R_{p\varepsilon}\, \varepsilon x_3 + x_3^{\,2}\, \varepsilon\, 'R_{\varepsilon\varepsilon}\, \varepsilon + x_2\, z\, \varepsilon\, x_3 = 0.$

Expression (30) is the sum of 3 nonnegative terms. Again, if $-P'E_{pp}P > 0$, then the alternative has no solution because $x_1 > 0$, and neither x_3 and x_2 can be negative.

Result 4

Under the assumptions of a small open and distorted economy described by system (22)-(24), a double dividend (dU > 0, −dz > 0, dT ≥ 0) exists for the class of piecemeal tax reforms that bring domestic relative tariffs toward uniformity by reducing them by a factor (1/(1+k_τ)), that is (dτ = Pk_τ) and that increase environmental taxes proportionally (dε = k_ε ε), if the initial tariff structure τ is such that (τ'E_{pp}P = −P'E_{PP}P) is strictly positive.

Empirical Section

We use a static and simplified version of the <u>*T*</u>*rade and* <u>*E*</u>*nvironment e*<u>*QUIL*</u>*ibrium* <u>*A*</u>*nalysis* (TEQUILA) model, which is a general equilibrium model developed by the OECD Development Centre. The full model is described in detail in Beghin et al. (1996). It is multi-sectoral (75 sectors), with a rich disaggregation of pollution-intensive sectors, including five mining and extraction sectors, four wood-based manufacturing sectors, four oil-based chemical industries, and eight mineral-based ones.

Output is characterized by CRS technology and the structure of production consists of a series of nested CES functions. Final output is determined from the combination of (non-energy) intermediate inputs and a composite bundle of energy and value added (labor, and capital). Non-energy intermediate inputs are assumed to be used in fixed proportions with respect to total non-energy intermediate demand. The energy-value-added bundle is further decomposed into a labor aggregate, and a capital-energy bundle. Labor demand is further decomposed into ten occupations. The capital-energy bundle is further disaggregated into capital demand and demand for an energy aggregate.

The energy bundle is itself decomposed into four base fuel components. In this production structure, pollution emissions are linked to intermediate consumption (inputs) rather than final output. Most existing CGE models investigating pollution issues assume a fixed proportion between sectoral output and emissions associated with that sector. This assumption implies an upward bias in the cost of environmental regulation because input substitution cannot abate pollution. By contrast, the TEQUILA model posits substitution possibilities between value added, energy, and non-energy intermediate goods, which allows the decrease of pollution associated with production if pollution taxes are put in place. This is a major improvement in the incorporation of pollution in economywide modeling.

The TEQUILA model relies on econometric estimates of the pollution effluents by sector explained by energy content and input use. Estimates of these input-based effluents intensities are obtained by matching data from a social accounting matrix disaggregated at the 4-digit ISIC level to the corresponding IPPS pollution database of The World Bank (Hettige et al.). Emissions are generated by both the final consumption and the intermediate use of polluting goods. Excise/effluent taxes are used to achieve pollution abatement. These taxes are measured as a unit of currency per unit of emissions and are uniform taxes per unit of effluent for all sectors. Since every sector has different effluent intensities, the pollution tax, expressed per unit of output, varies across sectors. The latter taxes are tacked on to the producer price of the polluting commodity.

Pollution by sector is characterized by a vector of 13 measures of various water, air, and soil effluents. In our static exercise on the double dividend, we focus on a subset of the 13 pollution types that are relevant to the ambient air pollution in the Greater Santiago Metropolitan Area. We consider bio-accumulative toxic metals released in air (BIOAIR); air pollutants, SO_2, NO_2, CO,

volatile organic compounds (VOC), and particulate intensity (PART). The emissions are recalibrated to describe a pollution inventory in Santiago, and then transformed into ambient pollution concentration via a dispersion model. We consider concentration of lead, SO_2, NO_2, CO, ozone, and small particulates (PM10). Concentrations affect morbidity and mortality measures through dose response functions. Utility is decreasing in mortality and morbidity losses.

We follow Espinosa, and Espinosa and Smith to break the separability between market decisions and environmental consumption. We assume that morbidity losses affect expenditures on health. They do so through the health services subsistence parameters of the Stone-Geary utility function. Further, we assume that the morbidity losses linearly affect these subsistence levels. The two are perfect substitutes. We use fourteen measures of morbidity (respiratory hospital admissions, emergency room visits, restricted activity days, bronchitis in children, asthma-attack days, respiratory symptom days, chronic bronchitis in adults, minor respiratory restricted activity days, coughing days, chest discomfort cases, eye irritation, headache episode, hypertension cases, and non-fatal heart attacks). The disutility of mortality and of IQ decrement is assumed additive to the utility of market consumption, as done in most investigations. The IQ decrement is considered to be a loss of human capital and lump with mortality damages. Both are considered as separable wealth effects. This is not a key assumption and results are qualitatively invariant to having IQ decrement separable or not from market-good consumption.

To calibrate the model and obtain morbidity damages, we multiply our estimates of morbidity measures by corresponding unit-cost coefficients and aggregate them. The implicit assumption is that morbidity damages are perfect substitutes with health services expenditures. The Stone-Geary level of minimum consumption has two components: an autonomous minimum level when pollution is null, and a second component made of health damages resulting from pollution. The unit-cost figures are based on Bowland. The unit cost measures represent scaled-down U.S. measures, which are rescaled by an adjustment factor, a traditional procedure in environmental economics. The adjustment factor is a monotonic transformation of the ratio of per capita GDP in Chile divided by the corresponding GDP per capita in the United States in 1992 PPP$. The implied elasticity used is unitary. The PPP conversion is based on the most recent World Bank's World Development Indicators for Chile in 1992. For mortality damages, we assume that the value of a statistical life (VSL) in Chile is $929,500 (1992 PPP). The latter

value corresponds to a VSL of about 2.446 million 1992 PPP dollars in the United States, assuming a VSL elasticity with respect to income equal to one.

The bulk of labor and capital income is distributed to one representative household owner of the fixed endowments of labor and capital. The household is assumed to maximize utility using the linear expenditure system. We characterize welfare changes using two exact measures (CV, EV). These welfare measures have three components: the change in disposable income, the change in expenditures induced by price changes and minimum health expenditures, and changes in mortality damages.

We calibrate the TEQUILA model using a detailed social accounting matrix (SAM) of Chile for 1992. The model is neoclassical, with all markets reaching equilibrium. Trade is modeled assuming goods are differentiated with respect to region of origin and destination. On the import side, we account for the heterogeneity of imports and domestic goods with the CES specification attributed to Armington. We assume a CET specification for domestic output, in which producers are assumed to differentiate between the domestic and export markets. We assume that Chile is a small country. Trade distortions are expressed as *ad valorem* tariffs. This assumption is consistent with the recent tariffication of most trade distortions in Chile following its structural adjustment reforms.

The SAM has the following aggregate information on tax revenues. In 1992, tax revenues came from four major sources in the Chilean economy. Value added taxes amounted to billion pesos 918.19, trade taxes to 469.91, direct tax on corporate income to 511.91, and other indirect taxes to 463.82. Taxes on labor income were only billion pesos 133.03 and direct taxes on other household income were relatively small as well (billion pesos 144.09). Hence, trade taxes were a main source of revenues, much more important than labor income taxes. By contrast, tariffs represent less than 2 percent of fiscal revenues in the United States.

We consider the following simple scenarios to show that a double dividend exists. We liberalize trade and impose a tax on PART effluents such that tax revenues remained unchanged. We do this for a full liberalization and a partial one in which tariffs are decreased by 50 percent. The latter scenario is motivated by the potential interaction between the two distortions, which could lead to perverse effect of one distortion on the other. This interaction was central in the double-dividend debate on labor market distortions. Alternative double-dividend scenarios with

taxes on other pollution emissions yield similar qualitative results and are not reported here. For example, trade liberalization combined with a tax on SO_2 or NO_2 leads also to a double dividend.

Results

In Table 1 we report results for the reference run (column (1)), trade liberalization with lump sum tax to hold tax revenue constant (column (2)), and the double dividend scenarios (columns (3) and (4)). The table provides figures in levels and in percent-deviations from the reference scenario.

First, we compare the reference run and the results for trade liberalization shown in column (2), to check that air pollution emissions expand with trade liberalization for most types of emissions and ambient pollution, and that health damages increase accordingly. With the exception of a reduction of CO, all emissions and ambient concentration increase with trade liberalization. Most health incidence measures deteriorate and health damages increase. Morbidity damages increase by 1.8% and mortality damage by 0.6percent. Hence, condition *(iii)* in Result 2 appears to be met in the case of our static model of the Chilean economy, that is $E_z{}' \, \partial z/\partial p \, P \geq 0$. Pollution expands with trade liberalization, although moderately.

The double-dividend scenarios with the tax on PART reduce all air pollution concentrations in Santiago. Health damages decreases and welfare increase because of greater allocative efficiency and reduced pollution. In alternative specifications not reported here, in which pollution does not enter utility, the same policy reform scenario leads to positive welfare gains, which come from greater allocative efficiency alone. Increases in welfare are typically moderate, but easily attained without tormenting the model's parameters. Hence, the cost of the double-dividend reform appears essentially negative, which is sufficient to establish a double dividend (Goulder).

The second double-dividend scenario combines a partial tariff reduction of 50 percent with the environmental tax on PART. We find no evidence of exacerbation of the trade distortion induced by the new environmental tax. We gauge the welfare effect of the trade distortion by (τ'dM) or by the change in tariff revenues between the two scenarios.[6] The introduction of the tax on PART changes tariff revenues by a negligible amount compared to the tariff revenues obtained under a partial trade liberalization alone (billion pesos 250.25 [not reported] versus 249.22 in column 4). Similarly, other distortions (VAT, production) are little affected by the changes in

tariffs and the introduction of the new tax. Hence, we strongly believe that in our Chilean illustration, the potential for an exacerbation of distortions is not present. We suspect that the exacerbation of distortions is more likely to occur in stylized models with a small disaggregation of factors and sectors and with a dichotomic characterization of the few goods, as either clean or "dirty" goods, as in Bovenberg and de Mooij.

Conclusions

Our paper contributes to the double-dividend debate with a formal analysis and some numerical evidence emphasizing the interaction of distortionary trade and environmental taxes.

The substitution of environmental taxes for trade distortions had been neglected in the double-dividend debate, despite its importance in emerging developing economies. We derived conditions for the existence of a double dividend for several specifications of preferences and policy menus. Under mild conditions, we establish the existence of a double dividend based on a nonspecific swap of environmental taxes for distortionary trade taxes. With a little more structure we establish the existence of a double dividend for policy reforms, which bring proportionally relative prices and taxes toward their shadow values.

We empirically explore the trade/environment double dividend with an applied general equilibrium model of the Chilean economy. The model includes many distortions and a vector of six air-pollution effluents and their health impacts in Santiago, including their welfare damages. Findings suggest solid evidence of a trade/environment double dividend in the case of Chile, although the estimated static welfare gains are moderate as is typically the case.

Our assessment of the recent literature on the double dividend is that there is some amalgamation of two issues: the existence of a double dividend and the difficulty in practically designing a tax menu that exhibits a double dividend. This paper addresses both points. Our analytical results show that existence is easy to establish, although practical guidance for policy design is less obvious to derive. By contrast, our numerical results show that double-dividend tax menus can be found in the trade/environment area in initial situations characterized by significant trade and environmental distortions. Our current work evolves toward identifying and designing specific policy menus in our analytical model that would yield various vectors of changes (dU, $-dz$, dT).

Table 1. Double-Dividend Static Simulations for Chile.

	Reference scenario (1)	Full trade lib. with lump sum tax (2)	% change from reference	PART tax and full trade lib.(3)	% change from reference	PART tax and partial trade lib. (4)	% change from reference
Tax Revenues[*]							
Corporate taxes	511.91	516.60	0.91	501.34	-2.07	506.86	-0.99
Household tax	144.09	676.33	369.38	143.40	-0.48	143.81	-0.19
Taxes on production	463.82	453.75	-2.17	442.65	-4.56	453.85	-2.15
Trade Taxes	469.91	0.00	-100.00	0.00	-100.00	249.22	-46.96
Pollution taxes	0.00	0.00		540.53		254.54	
Value-added tax	918.19	876.11	-4.58	877.18	-4.47	898.58	-2.14
Tax rate on PART 10^3 pesos/mt				13580		6130	
Welfare[*]							
Compensating variation	0.00	12.66		58.76		43.64	
Equivalent variation	0.00	13.20		58.97		43.73	
Household income	10970.72	10991.19	0.19	11009.69	0.36	10998.30	0.25
Morbidity damage	93.11	94.78	1.79	79.06	-15.09	86.31	-7.30
Mortality damage	440.99	443.63	0.60	421.32	-4.46	428.43	-2.85
Pollution emissions[**]							
BIOAIR	1143.51	1153.07	0.84	1250.11	9.32	1183.70	3.51
SO2	241429.12	246378.10	2.05	223363.02	-7.48	232724.93	-3.61
NO2	146950.81	149960.97	2.05	135967.12	-7.47	141657.87	-3.60
CO	60176.21	59137.44	-1.73	54603.03	-9.26	57500.12	-4.45
VOC	43110.49	43469.30	0.83	42800.02	-0.72	42974.71	-0.31
PART	43109.04	43799.30	1.60	39806.96	-7.66	41521.75	-3.68
Pollution concentration[***]							
Lead concentration	1.4992	1.4995	0.02	1.4978	-0.10	1.4899	-0.62
SO_2 concentration	61.534	62.050	0.84	58.641	-4.70	60.133	-2.28
NO_2 concentration	6.6070	6.6594	0.79	6.3076	-4.53	6.4619	-2.20
CO concentration	11.9474	11.7150	-1.94	10.9040	-8.73	11.4475	-4.18
PM10	112.598	113.140	0.48	107.792	-4.27	110.279	-2.06
Ozone	16.4705	16.5291	0.36	16.2430	-1.38	16.3625	-0.66
Selected health incidence[****]							
Premature mortality	751	773	2.93	585	-22.13	670	-10.69
Respiratory hospital admissions	4705	4761	1.21	4316	-8.26	4518	-3.97
Emergency room visits	27142	27798	2.42	21330	-21.42	24338	-10.33
Restricted activity days	6715310	6876395	2.40	5286977	-21.27	6026117	-10.26
Lower respiratory illness	56058	57403	2.40	44135	-21.27	50305	-10.26
Asthma attacks	1650057	1664971	0.90	1569096	-4.91	1611311	-2.35
Respiratory symptom day	34925947	35455688	1.52	30875826	-11.60	32975726	-5.58
Chronic bronchitis	3289	3368	2.40	2589	-21.27	2951	-10.26
Respiratory symptoms (children)	314	329	4.58	233	-25.71	275	-12.45
Chest discomfort episodes	381495	398549	4.47	285790	-25.09	335151	-12.15
Respiratory symptoms (adults)	432278	449615	4.01	333257	-22.91	384303	-11.10
Headaches	192414	177163	-7.93	123934	-35.59	159604	-17.05

[*] Tax and welfare figures which are in billion pesos, unless otherwise indicated. Deviations from the reference scenario are in percent.

[**] Pollution emissions are in metric tons per year for Chile.

[***] Concentrations are for Santiago and expressed in $\mu g/m^3$ (lead, SO_2, PM-10) pphm (NO_2, ozone), and ppm (CO).

[****] Mortality and morbidity figures are in numbers of cases per year

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ENDNOTES

[1]The cross-effect has generated a sub-debate on the level of the optimum environmental tax in reference to its Pigouvian level because of the potential increase in excess burden (see Oates for an overview).

[2] The economy can also be described as having a government buying a basket of goods g at world prices P such that P'g = T. The derivation of the comparative-statics of this alternative specification leads to equations identical to system (4)-(6) (see Falvey for such derivation). Separability in market goods and pollution creates a difficulty because it implies that an open economy either constrains its residual expenditure on pollution to be financed by exogenous income or that the economy does not reach balance of trade equilibrium with the rest of the world. This could be accommodated by a transfer between home and the rest of the world, which would offset the residual expenditure on pollution. If pollution is not an argument of the utility function, then such problem does not occur.

[3] Mangasarian makes a difference between semi-positive and non-negative real numbers by allowing the coordinates of the latter to be all zero. Semi-positive numbers can have any coordinate null, but not all of them (see page 8). We use theorem 4, on page 34. The primary and alternative problems are switched for convenience and without loss of validity.

[4]See Falvey for such definition.

[5] This expenditure function yields $E_u^* / E_{zj}^* = (P'E_{\Gamma}\Gamma_U) / (P'E_{\Gamma}\Gamma_{zj}) = ((P + \tau)'E_{\Gamma}\Gamma_U) / ((P + \tau)'E_{\Gamma}\Gamma_{zj}) = E_u/E_{zj}$.

[6] Abstracting from the revenue tax revenue constraint, the welfare effect of the trade distortions is $\tau'dM$ (see Beghin et al. [1997], equation (8)). By comparing the tariff revenues between the two scenarios (partial trade liberalization alone, and partial trade liberalization cum pollution tax), we can gauge how the magnitude of the trade distortion changes between the two reforms because of the new environmental tax.