DOUBLE DIVIDEND WITH TRADE DISTORTIONS.

ANALYTICAL RESULTS AND EVIDENCE FROM CHILE

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Abstract: This paper contributes to the double dividend debate with a formal analysis and some numerical evidence emphasizing trade and environmental distortions with a substitution of environmental taxes for trade distortions. We derive existence conditions and we empirically explore the trade/environment double dividend with an applied general equilibrium model of Chile.

Key words: Double dividend, trade and environment, piecemeal reform, policy coordination.

JEL classification: F13, Q28, and H21.

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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 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. Recent contributions include Bovenberg and Goulder, Espinosa, and Goulder. At the heart of the debate are second-best effects of the introduction of the new taxes which can exacerbate existing distortions via cross-price effects in consumption or production and hence can reduce welfare

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, which focuses on labor market distortions and corporate taxation.

We derive conditions for the existence of a double dividend for two definitions of the double 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. This abstraction means that either pollution reduction does not enter the utility of the consumer or that pollution is strongly separable from all private-good consumption. A few empirical papers have explicitly explored the valuation of the reduction in pollution, which corresponds more closely to the underlying theory (e.g., Espinosa).

We explore these two cases (nonseparable/separable) in our analysis using 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. In the case of separable utility (all Hicksian demands independent of pollution), the existence of a double dividend does not require any assumptions beyond convexity and integrability of consumption and production decisions in prices. Under general specification of preferences allowing for interaction between market demand and the pollution externality (i.e., Hicksian demands increasing in pollution), a trade/environment double dividend exists as long as trade liberalization increases aggregate pollution emissions for the whole economy. This assumption is consistent with stylized results coming from economywide models (Lee and Roland-Holst, Beghin et al. ([in press], and [1995]). We establish existence results for some specific types of tax reforms and initial tax structures.

Next, we empirically explore the trade/environment double dividend with an applied general equilibrium model of the Chilean economy. Based on our preliminary results, we find strong evidence of a trade/environment double dividend in the case of Chile.

The Basic Model

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 taxes are uniform. Hence, we have in mind a situation with an heterogeneous trade tax structure, which creates significant deadweight losses and 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 departure is the second distortion.

Under perfectly competitive markets, production decisions are modeled by a revenue or GDP function R with $R(P + \tau, \varepsilon, v) = \max_{(x, z)}\{(P + \tau)'x - \varepsilon z \mid (x, z) \text{ feasible given inputs } v\}$; 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: $R_p = x$; $R_\varepsilon = -z$; R_{pp} is the Hessian matrix 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.

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, $E_p = c$. 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)

(1) $P'(E_p - R_p) = 0$, (2) $z = -R_\varepsilon$, 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) $E_z^{*\prime}(-dz) = E_z^{*\prime} R_{\varepsilon\varepsilon} \, d\varepsilon + E_z^{*\prime} R_{\varepsilon p} \, d\tau,$ 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 properties and the balance of trade.

Note that equation (5) could be pre-multiplied by a vector of distortions $(E_z^* - \varepsilon)'$ to express the reduction in the environmental distortion. These could lead to two alternative definitions of the second dividend ($-E_z^{*\prime} dz$, 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). There are three variables of interest: one positive (dU), one semi-positive ($-E_z^{*\prime} dz$), and one nonnegative (dT). The theorem of the alternative states that either system (4)-(6) as a solution with dU positive, -dz semi-positive and dT nonnegative, or its alternative, described below, has a solution x, but never both. Assuming that the environmental dividend is defined as ($-E_z^{*\prime} dz$), the alternative system is

(7) $E_U^* \, x_1 - E_U \, x_2 \geq 0,$ (8) $-E_z^* \, x_1 + E_z \, x_2 + E_z^{*\prime} \, x_3 \geq 0,$ (9) $x_2 \geq 0,$

(10) $- x_1 \, P'(E_{pp}-R_{pp}) + x_2 \, (E_p - R_p) + x_3 \, E_z^{*\prime} \, R_{\varepsilon p} = 0,$ and (11) $x_1 \, P'R_{p\varepsilon} + x_2 \, R_\varepsilon + x_3 \, E_z^{*\prime} \, R_{\varepsilon\varepsilon} = 0,$

with x_1 and x_2 and x_3 being scalars. Slight modifications to equations (8), (10), and (11) occur if the alternative characterization of the environmental dividend is used ($-(E_z^* - \varepsilon)' dz$). The application of the theorem of the alternative relies on identifying conditions under which the alternative does not hold to prove the existence of a solution for the primary system.

As shown in the longer paper, a solution to the alternative requires two important conditions. First the cross-price responses of pollution distortions to tariff changes have to be negative "on average" in the sense that $P'R_{p\varepsilon}\, s > 0$, for any semi-positive number s. This condition requires that pollution, (and its damage if (E_z^*=s)), decreases with trade liberalization (s' ($\partial z/\partial P$) P < 0) "on average", or equivalently that environmental taxes induce an expansion of output "on average" (P' ($\partial R_p/\partial \varepsilon$) s > 0). Vector s allows to aggregate the pollution into a scalar.

Another requirement implied by the alternative is that the impact of the change in pollution on tax revenues ($dT/dz=E_u(E_z/E_u - E_z^*/E_u^*)$) be positive and, of course, larger than the impact of the same change on utility in absolute value ($\left| dU/dz \right| = E_z^*/E_u^*$), or that $E_z/E_u \geq E_z^*/E_u^*$. This is an empirical question in the sense that we do not see any obvious reason to motivate and justify such condition. The two normalized measures, E_z/E_u and E_z^*/E_u^*, are related but not equal. They are two measures of the absolute value of the marginal disutility of pollution but are evaluated at different price vectors, $P+\tau$ and P, respectively. As soon as one of these conditions is not met, the primary problem has a solution. We can state our first general result as follows:

Result 1.

Under the assumptions underlying our model of a competitive open distorted and polluted economy, and if pollution, z, is not an inferior input on average (i.e., s' $\partial z/\partial P$ P ≥ 0), then a double dividend exits for tax reforms swapping effluent taxes for trade taxes ($d\tau$, $d\varepsilon$), i.e., $dU>0$; $-E_z^{*\prime} dz \geq 0$; $dT \geq 0$.

Although general and useful in the sense of not requiring too much structure, the result provides little guidance to design a reform menu leading to a double dividend. Next we derive further results for specific reform menus.

Result 2.

Under the assumptions of result 1, a double dividend exists for the class of piecemeal tax reforms that bring

domestic relative tariffs towards uniformity by reducing them by a factor (1/(1+k_τ) and decrease proportionally environmental distortion by a factor k_ε, i.e., $d\varepsilon = k_\varepsilon(\varepsilon - E_z^*)$.

The intuition of this result 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. The result is reminiscent of earlier results established by Copeland, and Beghin et al. (1997), which show that coordinated reforms involving proportional reductions of all distortions improves welfare. Here we show, in addition, that a double dividend exits in the sense that behind the welfare improvement, pollution or its damage decreases while tax revenues are maintained.

Obvious corollary results obtain easily by setting ε to zero in the two previous results, i.e., 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.

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.

We assume that Hicksian demands (E_p) are independent of pollution levels, i.e., $E_{pz}=0$. System (4)-(6) becomes:

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

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

(13) $-dz = R_{\varepsilon\varepsilon}\, d\varepsilon + R_{\varepsilon p}\, d\tau$, and (14) $-E_u\, dU + dT = -R_\varepsilon\, d\varepsilon + (E_p - R_p)\, d\tau$.

The alternative system becomes quite simple. It is easy to show that the alternative has no solution other than 0. The alternative system is

(15) $E_U^* x_1 - E_U x_2 \geq 0$, (16) $x_3 \geq 0$, (17) $x_2 \geq 0$,

(18) $- x_1 P'(E_{pp}-R_{pp}) + x_2 (E_p-R_p) + x_3' R_{\varepsilon p} = 0$, and (19) $x_1 P'R_{p\varepsilon} + x_2 R_\varepsilon + x_3' R_{\varepsilon\varepsilon} = 0$.

It is easy to show that equation (16) and a transformation of equations (18) and (19) lead to a contradiction on the value x_3 can take, besides zero. The alternative has no solution except the null. Hence we have the following very general result in the case of separable preferences.

Result 3.

In a small open and polluted economy ridden by tariffs, a double dividend exists for the class of revenue neutral tax reforms that reduce trade distortions and introduce or increase environmental taxes, if pollution z does not enter preferences or is separable from commodity consumption, i.e., $E_{zp}=0$.

Corollary and sub-results can be obviously derived for more specific tax reform menus as is done in the first set of results.

How strong is the condition imposed to obtain results 1 and 2 ($s' \partial z/\partial p \, P \geq 0$)? Is it likely to be met in real economic conditions? Our previous work on Chile and Mexico 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. 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.

Empirical Section

We use a static version of the *Trade and Environment eQUILibrium Analysis* (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),

As in most CGE models, 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. The capital-energy bundle is further disaggregated into capital demand and demand for an energy aggregate. In this production structure, emissions are linked to intermediate consumption (inputs) rather than final output. Unlike in most existing CGE models investigating pollution, 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.

Here in this static exercise on the double dividend, we focus on a subset of the 6 pollution types, which 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).

We calibrate the TEQUILA model using a detailed social accounting matrix 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. Households are assumed to maximize utility using the linear expenditure system. We characterize welfare changes using two "exact" measures (CV, EV) and real GDP at market price as an approximation.

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 billions 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 quite important source of revenues and clearly 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 scenario to show that a double dividend exists. We remove all tariffs and impose taxes on effluents such that tax revenues remained unchanged. We plan to refine our illustration in the future. Future work would included the health impact and the valuation of the changes in emissions in Santiago. The initial results show the changes in emission and stop short of predicting ambient

pollution and the valuation.

Results

In Table 1, we present four simulations: A reference run, full trade liberalization, and then two double-dividend scenarios combining full trade liberalization and environmental reforms with revenue neutrality. The first of these two combined scenarios imposes a tax on PART; the second one imposes a uniform tax on all air pollution types (from NO_2 to PART) and an additional tax on BIOAIR, such that the latter does not increase. First, from column 2, we can see that pollution does expand with trade liberalization for five of the six pollution types. Hence, the sufficient condition for Result #1 to hold is likely to be met in the case of our static model of the Chilean economy. The marginal damage associated with the health impact of CO is much smaller than the marginal damage associated with micro particulates (about half of PART emissions) and ozone precursors (SO_2 and VOC). We are confident that once we will have completed our analysis for Santiago, we will have no problem showing more formally that $E_z^{*\prime}\partial z/\partial p\, P \geq 0$.

The first double dividend scenario reduces most of the pollution, except BIOAIR, which increases. We show this negative result to illustrate the difficulty of designing an environmental tax menu for multiple effluents because of substitution possibilities arising among pollution types. Most empirical papers focus on a single effluent, hence avoiding this problem. In the second scenario we impose an additional effluent tax on BIOAIR and scale both taxes down to satisfy revenue neutrality.

Welfare is characterized by equivalent and compensating variations for 5 household categories. All five households benefit from the reforms. Increases in welfare are small but easily attained without torturing the model or its parameters. Keep in mind that we have no explicit benefit from the reduced pollution. Hence, the cost of the second double-dividend reform appears essentially negative, which is sufficient to establish a double dividend. In fact, A reasonable conjecture is that the first double-dividend scenario would probably induce a reduction of environmental damages although emissions for BIOAIR increase slightly.

Tentative Conclusions

Our paper contributes to the double-dividend debate with a formal analysis and some numerical evidence emphasizing the interaction of trade and environmental distortions. The substitution of environmental taxes for trade distortions had been neglected in the double-dividend debate. We derived conditions for the existence of a double dividend for two definitions of the double dividend. 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. Initial findings suggest solid evidence of a trade/environment double dividend in the case of Chile.

Our assessment of the recent literature on the double dividend is that there is some confusion between the existence of a double dividend and the difficulty to design a tax menu that exhibits a double dividend. This first draft illustrates both points. On the one hand, our analytical results show that existence is easy to establish. On the other hand, our preliminary numerical results show that designing a "double-dividend" tax menu is less trivial than it appears, in part because of substitution possibilities among effluents. This source of difficulty was ignored before, though. If we myopically focused on a single pollution effluent, say PART or SO_2, we would have no problem establishing a dividend based on a reduction of trade taxes.

Our current work evolves around two efforts. First we have to recalibrate the dynamic TEQUILA model to the static application to translate national emissions into ambient pollution in Santiago. We also have to adjust the unit health damages (cost of unit incidence of morbidity and mortality) to the income level generated by the static model. The other effort is towards exploring and designing alternative policy menus, which would yield various vectors of changes (dU, -dz).

Table 3. Static simulations for Chile

Variables	**Reference**	**TRADE LIB**		**tax on part**	pollution in %	**tax on 6 Pollutants**	pollution in %
real GDP at market prices	14957.50	15145.78		15115.77		15112.40	
Compensating variation							
CV Household 1		4.4%		0.6%		0.7%	
CV Household 2		4.6%		1.1%		1.2%	
CV Household 3		4.6%		1.0%		1.0%	
CV Household 4		4.6%		0.4%		0.4%	
CV Household 5		4.9%		0.1%		0.2%	
Equivalent variation							
EV Household 1		4.5%		0.6%		0.7%	
EV Household 2		4.8%		1.1%		1.2%	
EV Household 3		4.8%		1.0%		1.0%	
EV Household 4		4.8%		0.4%		0.4%	
EV Household 5		5.0%		0.1%		0.2%	
Taxes							
corporate taxes	511.91	517.60735		504.00		502.26122	
direct taxes on households	144.09	145.80		143.10		142.46	
VAT	463.82	454.11		445.07		447.10	
trade taxes	469.91	0		0.00		0.00	
effluent tax revenues	0.00	0		512.38		499.41	
Pollution emissions							
BIOAIR	1143.51	1145.85	0.20%	1193.20	4.35%	1143.51	0.00%
SO2	241429.12	249639.88	3.40%	226304.27	-6.26%	229344.76	-5.01%
NO2	146950.81	151974.97	3.42%	137765.00	-6.25%	139614.40	-4.99%
CO	60176.21	59988.88	-0.31%	56092.93	-6.79%	56379.33	-6.31%
VOC	43110.49	44305.00	2.77%	43107.62	-0.01%	42632.35	-1.11%
PART	43109.04	44379.24	2.95%	40415.95	-6.25%	40923.42	-5.07%
Effluent taxes (10^9 pesos per mt)							
ε_{BIOAIR}	0.00	0		0.00		0.03202	
ε_{SO2}	0.00	0		0.00		0.00091	
ε_{NO2}	0.00	0		0.00		0.00091	
ε_{CO}	0.00	0		0.00		0.00091	
ε_{VOC}	0.00	0		0.00		0.00091	
ε_{PART}	0.00	0		0.01		0.00091	

Units are in 1992 billions pesos unless noted otherwise.

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