

Razmi, Arslan

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## Environmental Macroeconomics: Simple Stylized Frameworks for Short-Run Analysis

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# DEPARTMENT OF ECONOMICS

## Working Paper

Environmental Macroeconomics: Simple Stylized Frameworks  
for Short-Run Analysis

By

Arslan Razmi

Working Paper 2013-02



**UNIVERSITY OF MASSACHUSETTS  
AMHERST**

# Environmental Macroeconomics: Simple Stylized Frameworks for Short-Run Analysis

Arslan Razmi\*

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## Abstract

Environmental economics has mostly focused on micro issues pertaining to welfare and efficiency analysis. I develop a general framework to address short-run issues both for a closed economy and for an open one where emission permits are globally traded. Fiscal policy and emission permit issuance can both be used as short-run stabilization tools in a closed economy although the former is ineffective in a small open economy. In a large open economy, issuing emission permits in excess of international agreements remains an effective instrument, although it acts as a beggar-thy-neighbor policy, highlighting the crucial role of global monitoring on *macroeconomic* grounds.

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\*Department of Economics, University of Massachusetts, Amherst, MA 01003; email: arazmi@econs.umass.edu

# 1 Introduction and Background

Economics as a profession has, perhaps belatedly, starting taking seriously the environmental aspects of economic actions. An inordinate proportion of that attention has been focused on microeconomic analysis of efficiency issues based on representative agent optimization. As pointed out by Daly (1991), this lack of “environmental macroeconomics” is obvious when one looks at macroeconomic textbooks.

Environmental issues influence and are influenced by aggregate economic actions along many dimensions. In a world of the future where emission permits are likely to be internationally traded in growing volumes, how do these transactions affect exchange rates, relative prices, and the balance of payments? How do alternative short run stabilization policies affect a country and the rest of the world both in terms of output and emission costs?

Recent literature has begun to pay attention to some of these macroeconomic issues. Heyes (2000) develops a modified closed economy IS-LM model which incorporates an environmental constraint. This constraint takes the form of a curve labeled EE, along which the rate of re-generation of the environment exactly offsets its use, so that the stock of environment available is unchanging. This stock is predetermined at any given point in time; producers substitute between the use of the environment and capital in production. Raising the interest rate on borrowing for physical capital, therefore, encourages substitution towards less capital-intensive but more environment intensive production methods. Within this framework, Heyes explores the effects of fiscal and monetary policies. Considering expansionary fiscal policy, for example, the absence of an automatic adjusting mechanism means that an increased level of output and interest rate leaves the economy suspended at a point where the stock of environment is continuously shrinking. This leads Heyes (2000) to conclude that fiscal policy must be complemented by monetary policy to sustain a given stock of environment.<sup>1</sup>

Sim (2006) has argued that an automatic adjustment mechanism does exist that would ensure a stable stock of the environment in Heyes’s model. Consider a scenario where the environmental stock is continually degrading. In such a situation, Sim argues, public health is likely to deteriorate. This, in turn, is likely to lead to declining productivity and a halt to output growth. The economy, in other words, will hit a natural ceiling and create conditions for redemptive action to restore the environment.

Decker and Wohar (2012) explore Heyes’s model but assuming complementarity rather than substitutability between physical capital and the environment. This changes the relative roles of fiscal and monetary policy.

The papers cited above have made useful contributions to the literature on

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<sup>1</sup>In technical terms, the paper has a 3 equation system with only two unknowns: output and the interest rate. The system becomes overdetermined sans a third unknown, say in the form of monetary policy. In terms of logical structure, this is the IS-LM-EE counterpart to the open economy IS-LM model where a fixed exchange rate translates into a loss of monetary sovereignty in the presence of international capital flows.

environmental aspects of macroeconomic policies. The treatment of the issue however, appears to be unsatisfactory in the sense that there is a tension inherent in the overall framework used. Insofar as the model assumes underutilized resources, predetermined stocks of capital and environment, and fixed prices, the frame of reference must be short run. The assumption of substitution between factors in production and that of a steady state level of the environment, on the other hand, imply long-run closures. A more plausible treatment may be to assume complementarity in the short run but substitutability in the long run, as firms develop alternatives to current production methods.<sup>2</sup> Finally, these papers assume a closed economy thus neglecting issues arising from international trade in goods and assets.

This paper tries to develop some of these themes starting with a closed economy but then shifting to a more generalized open economy context. Throughout, I assume fixed commodity prices, underutilized resources, and predetermined stocks of capital and tradable emission permits in line with the short-run focus of the analysis. Emission permits have a dual nature, acting as inputs to production for firms and as tradable assets for speculators. The presence of money and bond markets gives the model an IS-LM flavor, or rather an IS-MP one with the difference of course that emission permit trading is incorporated. Asset demands depend on the rates of return, although trading in emission permits introduces output as a determinant in a non-standard manner.

Section 2 considers an economy that is hermetically sealed from the rest of the world. Thought experiments are carried out with fiscal policy and issuance of emission permits employed as temporary stabilization instruments. The next section shifts the focus to an open economy that is a price taker in the markets for emission permits and produces goods that are imperfect substitutes for foreign goods. The effect of permit issuance loses efficacy as an instrument for stabilization in this case. Finally, Section 4 extends the imperfect substitutes model to consider a more general two country world with flexible exchange rates. Feedback effects between the asset and goods markets lead to interesting consequences. In particular, expansionary fiscal policy inflates both countries through repercussion effects while an expansion of emission permits issued, by contrast, turns out to be a beggar-thy neighbor policy. Thwarting the possible use of the latter by countries facing unemployed resources may, therefore, require global supervision for macroeconomic reasons.

In a sense, this paper is an exercise in futuristic thinking. The world it considers is one where emission permits are being widely used and traded across countries.<sup>3</sup> Throughout, the focus is on simplicity of treatment rather than comprehensiveness, and I consistently eschew paraphernalia in favor of concise-

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<sup>2</sup>The question of substitution versus complementarity between human-made and natural resources has not yet been empirically resolved. Indeed studies find mixed results (see, for example, the survey of the empirical literature by Neumayer (2000)). The literature provides some support to the argument made by Griffin (1981), among others, that cross-sectional studies are more likely than time series studies to find substitution, since the former reflect long-run equilibrium results.

<sup>3</sup>See Jaffe et al. (2009) for a detailed discussion of issues related to international emission permit trading in the future.

ness. The idea is to show possible ways to incorporate environmental concerns in the analysis of aggregate (but simple) economies rather than carrying out policy experiments in exhaustive detail.

## 2 A closed economy

Consider first the simplest case; a self-contained economy that does not trade goods or assets with the rest of the world. The usual properties of the short-run demand-driven IS-LM (or IS-MP) model apply; goods prices are fixed and resources are underutilized. Built-in hysteresis, partly due to past investments means that substitution between factors is unlikely to be significant in the short run and labor, capital, and environmental resources are complements in production. The economy produces one good that is used for consumption and investment. The asset side consists of three assets: money ( $M$ ), bonds ( $B$ ), and emission permits ( $E$ ). These assets are gross substitutes in asset portfolios. The stocks of capital, bonds and emission permits are pre-determined variables.

In line with the IS-MP framework, we assume that the central bank sets interest rates based on standard monetary policy reaction functions, and trades money for bonds accordingly. A booming economy invites higher interest rates while slack in factor markets leads to reduced interest rates. Thus, the money supply is endogenous and responds passively to Central Bank actions. This assumption is purely to simplify the analysis, and assuming an exogenous supply of money will not qualitatively affect the analysis.

The specification of the emissions market merits a closer look. Based on its international agreements, the government announces issuance of a fixed number of emission permits over multiple sub-periods. Each permit allows for a fixed amount of carbon emissions. These permits are auctioned off and traded in permit markets. Agents may buy these permits for actual production (firms requiring one permit per unit of production) or for speculative purposes, based on an expected “normal” or long-run equilibrium price of the permits. Given the short-run nature of the analysis, we assume that this expected price does not change and any actual deviation from it is considered to be temporary (i.e., regressive expectations). Permits can be banked by speculators for trade between periods.<sup>4</sup>

These motives govern the demand for emission permits. For example, if aggregate spending is expected to be low over a certain sub-period, firms buy fewer emission permits for production, bringing down the price of these permits

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<sup>4</sup>One could think here of the European Union’s Emissions Trading Schemes (EU ETS), which issue permits for multiple periods and allow for trading across time. Companies and private individuals can trade through brokers much like in a stock market. Notice that we allow for banking but not for borrowing of permits, i.e., purchasing permits that have not yet been issued. Insofar as the aim of a cap-and-trade system is to gradually reduce emissions over time, borrowing is unlikely to be a feature of such schemes. This probably explains why existing EU ETS provisions strictly constrain borrowing within a very narrow window of time while allowing for almost unlimited banking within a phase. See, for example, Chevallier (2012).

relative to the expected price over the period, raising expected returns from holding permits, and triggering speculative buying in pursuit of the expected capital gains. Thus, speculators play the key role of soaking up excess permits in periods of low firm output and releasing banked permits in periods of high output, and changes in expected returns ensure that the market for newly issued permits clears in each subperiod. Moreover, risk aversion and lack of perfect foresight means that agents need not necessarily drive up the price of permits to their expected long-run level in each sub-period.

A concrete example may help describe the mechanisms at work. Suppose the government promises to issue 1 million permits for each of the next 5 sub-periods. Suppose also that the expected normal equilibrium auction price, given production costs, is  $\bar{\delta}$  dollars per permit. Finally, suppose that the market for emission permits is initially in equilibrium, with speculators holding the permits left over after firms satisfy their demand at the long-run equilibrium price. An exogenous increase in aggregate demand greater than that expected by firms at the beginning of the next sub-period then creates a scarcity of permits, driving their price,  $\delta$ , up in the market as speculators are willing to sell previously banked permits to the producers at the higher price (and hence derive capital gains). Conversely, a decline in aggregate demand and output drives down the demand for permits required for production and creates an excess supply of these permits. Speculators absorb the excess supply (i.e., bank the permits) at lower prices (and hence for expected capital gains).

Notice that emission permits here have a dual nature. That firms require these in order to produce goods makes them an input to production. Insofar as these are traded in asset markets, can be traded across time, and yield returns to speculators, these act as assets too. To put it in starker terms, emission permits act as intermediate inputs for firms and as assets for speculators.

A feedback exists between the asset and goods markets both through returns on bonds and emission permit prices. Higher bond yields (and real interest rates) discourage investment and consumption spending. Higher permit prices – which correspond to lower expected returns – insofar as they impose a cost on future production, too tend to reduce spending on capacity expansion.

Our discussion so far can be summarized with the help of the following system of equations:

$$y = a(y, r, r_e) + g \tag{1}$$

$$r = r(y) \tag{2}$$

$$\bar{e} = e(y, r, r_e) \tag{3}$$

$$r_e = \frac{\Delta\delta^{\text{exp}}}{\delta} = \frac{\theta(\bar{\delta} - \delta)}{\delta}; 0 < \theta < 1 \tag{4}$$

where  $y$ ,  $a$ , and  $g$  stand for real output, expenditure, and government spending, respectively,  $r$  and  $r_e$  denote the expected returns on bonds and emission

permits,  $\Delta\delta^{\text{exp}}$  is the expected change in permit prices, while  $\bar{e}$  represents the quantity of permits issued in a subperiod. Regarding the partial derivatives,  $a_y, a_{r_e}, r_y > 0$  while  $a_r < 0$ . As discussed earlier, the partial  $a_{r_e}$  reflects the positive effect of a rise in expected capital gains from holding emission permits (i.e., the positive effect of a fall in the price of emission permits on spending via investment in capacity).

Equations (1) and (2) are part of the standard IS-LM model (except for the endogenous money assumption). Equation (3) captures the emissions market clearing condition. With a fixed amount of permits available over the period of analysis, changes in output and relative asset returns help equilibrate the market.<sup>5</sup> Based on portfolio and production considerations, the partials are as follows:  $e_y, e_{r_e} > 0, e_r < 0$ . An increase in domestic output raises demand for permits, as do higher expected returns from holding these assets. A rise in returns to the holdings of bonds, on the other hand, reduces the speculative demand for holding emissions permits. Equation (4) simply captures the behavior of expected returns on permits, which is driven by regressive expectations.

Substituting eqs. (2) and (4) into eqs. (1) and (3), and re-writing the latter leaves us with a system of two equations in  $y$  and  $r_e$ .

$$IS : IS(y, \delta, g) = 0 \quad (5)$$

$$EE : EE(y, \delta, \bar{e}) = 0 \quad (6)$$

where  $IS_y = 1 - a_y - a_r r_y > 0$  as long as the marginal propensity to spend out of income does not exceed unity by too much,<sup>6</sup>  $IS_\delta = a_{r_e} \theta \bar{\delta} / \delta^2 > 0$ ,  $IS_g = -1$ ,  $EE_\delta = e_{r_e} \theta \bar{\delta} / \delta^2 > 0$ , and  $EE_{\bar{e}} = 1$ . The effect of increased output on the excess supply of emission permits is ambiguous. The direct effect is to raise firm demand for permits. The secondary effect via the rise in the interest rate is to lower speculative demand for permits. We assume that the direct effect dominates so that  $EE_y = -(e_y + e_r r_y) < 0$ ; that is, an excess demand of permits is created which puts upward pressure on  $\delta$ .

The effects of short-run policy shocks can now be easily described (see the Appendix for the detailed mathematical solutions and Table 1 for a summarized presentation of the results derived from this and later sections). An increase in government spending creates excess demand for goods. Given excess capacity, firms respond by increasing output. The excess demand spills over into the

<sup>5</sup>In the presence of banking, the market clearing condition is, strictly speaking, not independent of history, and should in mathematical terms be expressed as:

$$\underline{e} + \bar{e} = \int_0^{t-1} e(\cdot) dt + e(\cdot)$$

where  $\underline{e}$  represents permits issued in the past sub-periods and banked for future use. Given that the (banked) supply of permits is pre-determined at time  $t$ , however, the expression above is essentially similar to the condition expressed in equation (3).

<sup>6</sup>That is,  $a_y < 1 - a_r r_y$ . Note that  $a_r r_y < 0$ .



market for emission permits as a result, putting upward pressure on the price of these assets.

With a market for emission permits, the government can use the supply of this asset as a stabilization tool.<sup>7</sup> For example, increased issuance of emission permits creates excess supply in the market for these assets, raising the expected rate of return required that would induce speculators to hold them. Reduced permit prices and higher returns, in turn, boost investment spending in future capacity, and hence output.

Thus, both a fiscal expansion and increased permit issuance act to boost output in the economy, although the impact on permit prices moves in opposite directions. This latter conclusion generates interesting results in the more involved open economy analysis that follows shortly.

### 3 A small open economy

Next, consider a small open economy that trades goods and emission permits with the rest of the world, the latter at prices given by the world market.<sup>8</sup> The country produces a good that is an imperfect substitute for foreign goods. Goods prices are fixed and normalized to unity. With a flexible exchange rate, relative prices can change between countries, influencing competitiveness and the trade balance. Moreover, exchange rate expectations now influence the equilibrium rate of return on internationally traded emission permits. I assume these expectations to be static for simplicity. Thus, the small open economy versions of equations (1)-(3) take the following form:

$$y = a(y, r, r_e^*) + t(y, x) + g \quad (7)$$

$$r = r(y) \quad (8)$$

$$\bar{e} = e(y, r, r_e^* + \hat{x}^{\text{exp}}) \quad (9)$$

where  $r_e^*$ ,  $x$ , and  $t$  denote the (international) returns on permits, exchange rate (the domestic currency price of foreign currency) and the trade balance, respectively, while  $\hat{x}^{\text{exp}}$  represents the expected depreciation of the exchange rate. The foreign variables are distinguished by the superscript ‘\*’. Regarding the partial derivatives, assuming that the Marshall-Lerner condition is satisfied,  $t_x > 0$ , while  $t_y < 0$  in the standard manner. Speculative demand for permits is a positive function of the internationally given returns on these in domestic

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<sup>7</sup>As long as the tool is not used frequently enough to affect expectations. In other words, as long as it is reasonable to consider a change in  $\bar{e}$  as a one time exogenous shock. The efficacy of repeated use is subject to the Lucas critique.

<sup>8</sup>Note that the economy is small in two senses: first, in the standard Keynesian small country manner, imports do not affect foreign income, and second, the price of emission permits is internationally given.

currency terms. All quantities are expressed in terms of the price of the Home good, which can be normalized to unity without loss of generality.

Now that we allow for cross-border trade in permits, another look at this market is warranted. Notice that equation (9) implicitly assumes that only domestic firms use domestically issued permits for production. Put differently, a producer can only utilize a permit within the country that issued it.<sup>9</sup> This restriction, although fairly innocuous here, significantly simplifies the analysis in the next section where I relax the small open economy assumption. Note also that, with the price of permits now internationally determined, permit price equalization and permit return equalization are interchangeable conditions in the presence of regressive expectations. We can, therefore, ignore explicit modeling of permit price expectations along the lines of equation (4).

Once again, the system can be consolidated into two equations in two variables. Since returns on emission permits are now internationally given, these two variables are  $y$  and  $x$ .

$$IS : IS(y, x, r_e^*, g) = 0 \quad (10)$$

$$EE : EE(y, r_e^*, \bar{e}, \hat{x}^{\text{exp}}) = 0 \quad (11)$$

where  $IS_y = 1 - a_y - a_r r_y - t_y > 0$ ,  $IS_x = -t_x < 0$ ,  $IS_{r_e^*} = -a_{r_e^*} < 0$ ,  $EE_{r_e^*} = -e_{r_e^*} < 0$ , and  $EE_{\hat{x}^{\text{exp}}} = -e_{\hat{x}^{\text{exp}}} < 0$ . The remaining partials are unchanged from Section 2. The effect of increased output in creating excess supply of goods is bolstered in the open economy case by the resulting trade deficit. Increased competitiveness due to a depreciation (increase in  $x$ ) switches demand toward domestic goods. Increased expectations of currency depreciation or increased international returns on permits raise the expected return on these in domestic currency terms, boosting demand for them.

A fiscal expansion has no effect on output, which now is pinned down in the market for emission permits. The effect of increased government spending falls entirely on the exchange rate, which must appreciate in order to remove the excess demand for domestic goods created by the fiscal expansion.

Can we say anything about the external balances? With an appreciated exchange rate and an unchanged level of income, it is clear that the economy is running a trade deficit at the new equilibrium. The trade deficit must be financed by a capital account surplus (foreign purchases of domestic emission permits) at the internationally given rate of return.

Next, suppose that the government expands the amount of emission permits issued per period, perhaps in violation of internationally agreed limits. This creates an excess supply of permits, putting upward pressure on the returns required to motivate speculators to hold these permits. Given  $r_e^*$  and static expectations, output must rise to remove the excess supply through greater firm demand for permits. Rising output is sustained by exchange rate depreciation,

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<sup>9</sup>The demand for emission permits is not a function of foreign output. For example, Japanese firms cannot use Swedish permits to produce in Japan.

which switches domestic and international demand toward domestic goods. As to the effects on the external accounts, the higher output level and the depreciated exchange rate at the new equilibrium have opposite effects on the trade balance. Analyzing the income-expenditure balance helps resolve the ambiguity. Higher income causes a positive but lesser increase in expenditure, given our earlier assumption regarding the marginal propensity to spend. The higher new equilibrium interest rate magnifies this gap. Clearly a trade surplus emerges at the new equilibrium. The trade surplus must be financed by a capital account deficit (domestic purchase of foreign emission permits).

Finally, consider the effect of increased expectations of currency depreciation (a rise in  $\hat{x}^{\text{exp}}$ ). The immediate impact is to raise the returns on holding emission permits in domestic currency terms, generating an excess demand in this market. Equilibrium is now consistent with a lower level of output, which lowers the demand for permits, and is, in turn, sustained by an exchange rate appreciation that shifts demand away from domestic goods.

Thus, in stark contrast to the closed economy case, a fiscal expansion has no effect on output in a small open economy in the presence of internationally traded emission permits and a flexible exchange rate. Expanded issuance of emission permits is more effective, although, as we discover in the next section, it comes at the cost of the rest of the world once we relax the small economy assumption. We have already caught a glimpse of the underlying reason; permit expansion creates a trade surplus in the Home country. This has interesting implications which become clear in the more involved model of the next section.

## 4 An open economy two country model

Finally, let's turn to the most general case. Consider a two-country world with flexible exchange rates. With two large countries, the trade balance in each country is a function of output in *both* countries, necessitating explicit consideration of both goods markets. Again, the asset side consists of three assets: money, bonds, and emission permits which are gross substitutes in asset portfolios and bonds are assumed not to be traded across international borders. The stocks of bonds and emission permits continue to be pre-determined variables.

The following set of equations captures the system. Again, with regressive expectations, the condition specifying equalization of returns on permits is interchangeable with that of permit price equalization, obviating the need to explicitly model  $r_e$  in terms of permit price movements.

$$y = a(y, r, r_e) + t(y, y^*, x) + g \tag{12}$$

$$y^* = a^*(y^*, r^*, r_e^*) - xt(y, y^*, x) \tag{13}$$

$$r = r(y) \tag{14}$$

$$r^* = r^*(y^*) \quad (15)$$

$$\bar{e} = e(y, r, r_e) \quad (16)$$

$$\bar{e}^* = e^*(y, r^*, r_e^*) \quad (17)$$

$$r_e = r_e^* + \hat{x}^{\text{exp}} \quad (18)$$

where  $a_{y^*}^*, a_{r_e^*}^*, t_{y^*}, r_{y^*}^*, e_{y^*}^*, e_{r_e^*}^* > 0$ , while  $a_{r^*}^*, e_{r^*}^* < 0$ , the remaining partials having already been defined. Equations (16) and (17) capture the Home and Foreign emissions market clearing conditions. With a fixed amount of permits available over the period of analysis, changes in output and relative asset returns help equilibrate the market. Equation (18) is the balance of payments equation. It reflects the equalization of expected return on permits in the presence of international arbitrage and perfect permit mobility across borders. I continue to assume static exchange rate expectations.

Equations (16) and (17) can be re-written in a slightly modified form:

$$r_e = r_e(y, r, \bar{e}, e); \quad r_{e_y}, r_{e_e} < 0, \quad r_{e_r}, r_{e_{\bar{e}}} > 0 \quad (16a)$$

$$r_e^* = r_e^*(y^*, r^*, \bar{e}^*, e); \quad r_{e_y}^*, r_{e_e}^* < 0, \quad r_{e_r}^*, r_{e_{\bar{e}}}^* > 0 \quad (17a)$$

The returns to holding emission permits depend on their supply, the demand for these permits for real output, and returns on alternative assets.

Next, substituting equations (14), (15), (16a), and (17a) into equations (12) and (13) and manipulating allows us to write down the “global” IS equation:

$$IS(y, y^*, \bar{e}, \bar{e}^*, g) = x(y, y^*, \bar{e}, g) - x^*(y, y^*, \bar{e}^*) = 0 \quad (19)$$

Satisfaction of equation (19) ensures that the markets for goods and services as well as the asset markets are simultaneously in equilibrium in *both* countries. Assuming initially balanced trade,<sup>10</sup> the partials are as follows:  $IS_y, IS_{y^*} > 0$ , while  $IS_{\bar{e}^*}, IS_{\bar{e}}, IS_g < 0$ .<sup>11</sup>

The two goods markets are connected through international trade, which plays a crucial role. A real depreciation (i.e., an increase in  $x$ ) creates excess demand for Home goods and excess supply of Foreign goods. Real income rises domestically and falls abroad as a result.<sup>12</sup> A rise in government spending creates excess demand for goods in Home. Domestic output rises as a result. The rise in domestic output at a given exchange rate spills over into the foreign

<sup>10</sup>So that income effects are ruled out.

<sup>11</sup>The Appendix provides more detailed expressions for these partials.

<sup>12</sup>Again given the standard assumption in Keynesian models that increased output creates excess savings.

market, creating excess demand there. The exchange rate must, therefore, appreciate to maintain global goods market equilibrium. The appreciation causes foreign equilibrium output to fall.

By lowering the price of permits, an increase in the supply of emission permits in Home boosts demand for domestic goods, and has effects on outputs similar to those of a rise in  $g$ . Increased issuance of permits in the rest of the world, on the other hand, creates excess demand for the foreign good, raising foreign output. Again, an appreciation is required to neutralize the spillover into the domestic goods market.

Turning to the balance of payments, plugging equations (16a) and (17a) into equation (18) yields:

$$BP(y, y^*, \bar{e}, \bar{e}^*) = r_e(y, r, \bar{e}) - r_e^*(y^*, r^*, \bar{e}^*) - \hat{x}^{\text{exp}} = 0 \quad (20)$$

where  $BP_y, BP_{\bar{e}^*} < 0$  while  $BP_{y^*}, BP_{\bar{e}} > 0$ . An increase in domestic output or the volume of emission permits issued abroad moves the differential in returns on permits in favor of the Foreign country.<sup>13</sup> Investors shift their portfolios towards foreign assets, putting downward pressure on the domestic balance of payments. The reverse is true if foreign output rises or Home policy makers issue more permits (so that they have to offer higher returns on domestic permits).

Our framework is now complete. The system consists of equations, (19) and (20), in two variables, domestic and foreign income. Given the more involved nature of the analysis, we will supplement the discussion with graphical illustration to help keep track of things. Figure 1 captures the model in  $y - y^*$  space. The IS curve represents points along which the goods *and* asset markets are in equilibrium in both countries. More specifically, it gives us information on how Home and Foreign income must change in response to a change in the exchange rate. For reasons already discussed, it is downward sloping. The magnitude of the slope depends, among other things, on the sensitivity of the central bank to the state of the economy, the relevant income and price elasticities of trade flows, and the degree of substitutability between assets.

Since the two countries are linked through trade in goods, keeping track of the exchange rate helps understand the impact of various shocks. As we move along the IS curve in a north-west direction, the exchange rate appreciates. The resulting trade deficit is supported by a decline in domestic output along with a rise in foreign output.

The BP curve is upward sloping. A rise in domestic output leads to a differential between returns on permits in favor of the other country. Capital flows out and Home develops a balance of payments deficit. Foreign output must rise to lower  $r_e^*$  and remove the deficit. Note that  $r_e$  and  $r_e^*$  both decline as we move along BP in the north-east direction.

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<sup>13</sup>As before, the effect of an increase in output is somewhat ambiguous. We continue to assume that the direct effect dominates, both here and in the case of a rise in Foreign income.

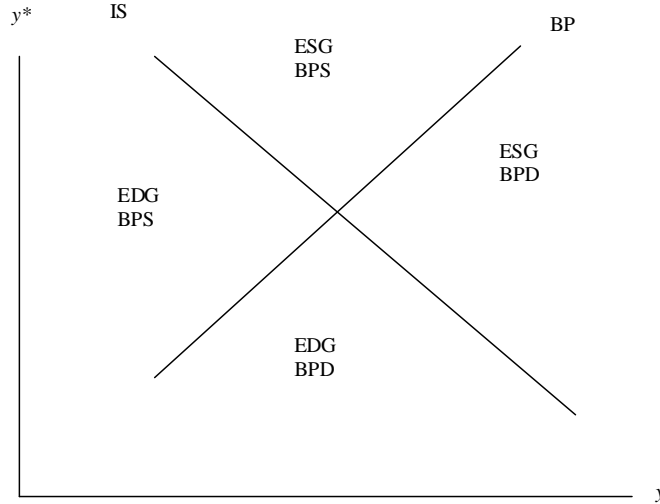


Figure 1: The basic framework. EDG(ESG) denotes excess demand (supply) for (of) goods while BPD (BPS) denotes balance of payments deficit (surplus)

#### 4.1 An increase in government spending

Our first policy experiment again involves higher government spending on goods. Increased demand for goods raises output and demand for emission permits, putting downward pressure on the expected returns. The IS curve shifts to the right as equilibrium in the global goods and assets markets is now compatible with a higher level of domestic output. That's the first order effect as shown in the movement from point A to point B in Figure 2. At B, the expected yield on domestic permits is lower. Beyond this point, the exchange rate appreciates accompanied by a shift in global spending from domestic to foreign goods. The new equilibrium at C reflects equalization of returns on emission permits across markets and a rise in both Home and Foreign income. Expansionary fiscal policy in one country helps the world as a whole.

To understand what happens to the trade balance at the new equilibrium, it is easier to consider the foreign country. At the new equilibrium, foreign output and interest rate are higher, while the return on foreign emission permits is lower. All of these imply that foreign output has risen relative to expenditure. It follows that Foreign (Home) must have a trade surplus (deficit), as in the case of the small open economy. The trade deficit in Home is accompanied by a capital account surplus and appreciation of the Home currency. Indeed it is this appreciation that gives a boost to the rest of the world.

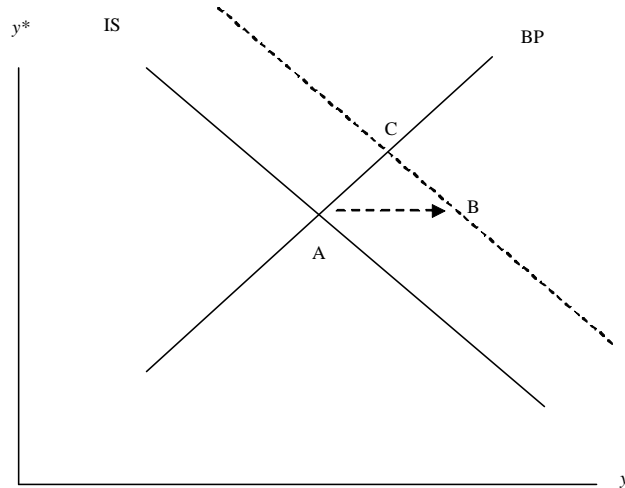


Figure 2: Expansionary fiscal policy

## 4.2 Increased issuance of emission permits

Next, suppose that Home policy makers attempt to skirt international restrictions and issue more emission permits than agreed upon. What are the effects of an increase in  $\bar{e}$ ?

The direct effect of such a policy action is to create an excess supply of permits, putting upward pressure on the returns required in order to convince speculators to hold the excess permits. International capital flows in, creating a balance of payments surplus. The international permit return parity condition can now only be satisfied if domestic output rises while foreign output falls. Increased investment spending in Home caused by the lower price of emission permits makes the former possible. The depreciation that accompanies higher domestic output acts as a negative shock for the rest of the world and makes the latter possible.

Graphically, both curves shift to the right. At a given level of foreign income, both goods and asset market equilibrium as well as the balance of payments equilibrium require a higher level of domestic income. As shown in the mathematical appendix, however, the IS curve, shifts more than the BP curve.

Turning to the trade balance,  $y^*$  and  $r^*$  are lower at the new equilibrium, implying that Home has a trade surplus, i.e., income falls relative to expenditure in Foreign. The Home trade surplus is what transmits as a negative shock to the other country, bringing down its output. We saw the trade surplus develop in the small open economy of the previous section. The present more general

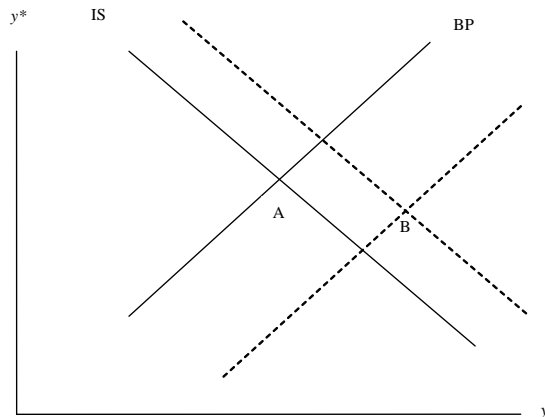


Figure 3: Excessive issuance of emission permits

framework helps us see the output effects on the rest of the world.

In sum, unlike fiscal expansion, emission permit expansion is a beggar-thy-neighbor policy. The trade balance makes the difference as in one case it acts as a positive shock and in the other as a negative shock for the rest of the world. Home benefits but only at the expense of the rest of the world. Notice that Home policy makers need not explicitly contravene international agreements by issuing more emission permits. The same consequences would follow if they were to reduce domestic *demand* for emission permits, perhaps by taxing speculative holdings or through other means.

### 4.3 Heightened Expectations of Currency Depreciation

Finally, consider the effect of a change in expectations regarding the exchange rate. Specifically, suppose agents come to expect a depreciation. Such an expectation means that capital flows out as foreign assets become more attractive in domestic currency terms. Only a higher return on domestic permits is now consistent with balance of payments equilibrium. An appreciation that shifts demand from domestic to foreign goods generates such a differential by reducing domestic output. In graphical terms, the AA curve shifts left and up since a lower level of  $y$  and a higher level of  $y^*$  are required to generate the excess supply of domestic permits and excess demand for foreign permits needed to sustain a higher  $r_e$ .

Since the new equilibrium involves moving up the IS curve, the exchange rate has appreciated. There is a trade deficit and a capital account surplus at the new equilibrium. It is the former that gets transmitted to the rest of the world as a positive real shock. It helps equilibrate the domestic and foreign



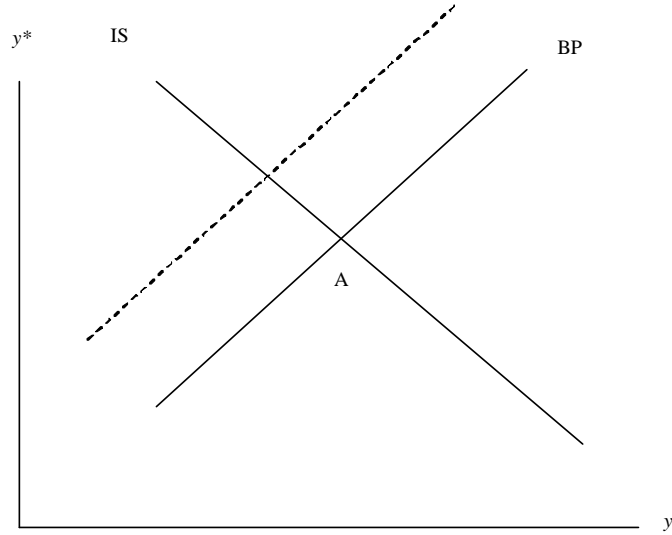


Figure 4: An increase in the expected depreciation of the exchange rate

goods markets in the aftermath of the expenditure switching that shifts demand from Home to foreign goods. From an income-expenditure perspective,  $y$  and  $r$  have declined, while  $r_e$  has risen. All three changes imply a decline in income relative to expenditure, i.e., a trade deficit in Home at the new equilibrium.

Table 1: Comparative statics: The second row displays the various shocks considered while the following rows capture the effect on endogenous variables

	Closed economy			Small open economy			Two country case		
	$\uparrow g$	$\uparrow \bar{e}$	$\uparrow \hat{x}^{\text{exp}}$	$\uparrow g$	$\uparrow \bar{e}$	$\uparrow \hat{x}^{\text{exp}}$	$\uparrow g$	$\uparrow \bar{e}$	$\uparrow \hat{x}^{\text{exp}}$
$y$	+	+		0	+	-	+	+	-
$r_e$	-	+					-	+	+
$x$				-	+	-	-	+	-
$t$				-	+	-	-	+	-
$y^*$							+	-	+

## 5 Concluding remarks

Economic analysis of environmental issues has largely taken a microeconomic approach with emphasis on efficiency, welfare, and cost-benefit issues. A few recent papers have explored simple frameworks for macroeconomic analysis. These models assume price stickiness and factor substitution. While the former assumption makes sense in a short-run framework, the latter appears to be unsatisfactory. Moreover these contributions do not address the role of emission permits as tradable assets and ignore open economy issues.

This paper is an attempt to suggest general short-run approaches to addressing these issues. The general approach bears resemblance to the Mundell-Fleming family of models. Rather than pursuing comprehensiveness, the aim is to create simple structures in order to tease out insights and offer flexible frameworks for future adaptation. The first part develops a closed economy framework where emission permits are traded within the country. Goods prices are rigid, factors are complements, and resources are underutilized. With these properties, both fiscal expansion and increased issuance of emission permits are effective policy tools. Fiscal policy, however, loses effectiveness once we open up the economy to trade in goods and emission permits as long as the economy is not large enough to impact the rest of the world in these markets. It does, however, create a trade deficit and currency appreciation. The contrast with permit expansion is dramatic, as the latter generates output changes and a trade surplus.

The effects of stabilization policies on the trade balance fully come into play once we broaden our framework to incorporate a two country world. Fiscal expansion now becomes effective, not only for Home but also for the rest of the world, thanks to the trade deficit generated in the former. A win-win scenario emerges.

Undermining international agreements by excess issuance of emission permits achieves similar results for the Home economy but constitutes a *beggar-thy-neighbor* policy. The intuition is simple. The shock is transmitted to the foreign goods market through the trade surplus created in Home. Since, therefore, there is an incentive to cheat, tight global monitoring is required in a world economy with unemployed resources and internationally tradable environmental permits.

The work presented here is suggestive. Given the short-run nature of the analysis, the volume of emissions rises and falls with output (through the use of environmental permits). An analysis of longer-run issues would require incorporation of technological change and factor substitution. Moreover, as the period of analysis expands, renewable resource scarcity becomes an important determinant of permit pricing. Countries differ in their structures (i.e., in terms of level of income, degree of industrialization, and resource intensity of production). Production of a good in a highly industrialized economy may, for example, create less pollution per unit than production of the same good in a developing country. Future work will extend the ideas presented here to analyze these important considerations.

## 6 Mathematical Appendix

### 6.1 Closed Economy Model

$$\frac{dy}{dg} = \frac{e_{r_e} \theta \frac{\bar{\delta}}{\delta^2}}{\Delta_1} > 0$$

$$\frac{d\delta}{dg} = \frac{e_y + e_r r_y}{\Delta_1} > 0$$

$$\text{where } \Delta_1 = \begin{vmatrix} IS_y & IS_{r_e} \\ EE_y & EE_{r_e} \end{vmatrix} = [e_{r_e}(1 - a_y - a_r r_y) + a_{r_e}(e_y + e_r r_y)] \theta \frac{\bar{\delta}}{\delta^2} > 0.$$

$$\frac{dy}{d\bar{e}} = \frac{a_{r_e} \theta \frac{\bar{\delta}}{\delta^2}}{\Delta_1} > 0$$

$$\frac{d\delta}{d\bar{e}} = -\frac{1 - a_y - a_r r_y}{\Delta_1} < 0$$

### 6.2 Small open economy Model

$$\frac{dy}{dg} = 0$$

$$\frac{dx}{dg} = \frac{e_y + e_r r_y}{\Delta_2} < 0$$

$$\text{where } \Delta_2 = \begin{vmatrix} IS_y & IS_{r_e} \\ EE_y & EE_{r_e} \end{vmatrix} = -t_x(e_y + e_r r_y) < 0.$$

$$\frac{dy}{d\bar{e}} = -\frac{t_x}{\Delta_2} > 0$$

$$\frac{dx}{d\bar{e}} = -\frac{1 - a_y - a_r r_y - t_y}{\Delta_2} > 0$$

$$\frac{dy}{d(\hat{x}^{\text{exp}})} = \frac{t_x e_{\hat{x}^{\text{exp}}}}{\Delta_2} < 0$$

$$\frac{dx}{d(\hat{x}^{\text{exp}})} = \frac{(1 - a_y - a_r r_y - t_y) e_{\hat{x}^{\text{exp}}}}{\Delta_2} < 0$$

### 6.3 Two Country Model

With balanced trade in the neighborhood of the initial equilibrium, the slopes of the two curves are given by:

$$\begin{aligned}\left.\frac{\partial y^*}{\partial y}\right|_{IS} &= -\frac{IS_y}{IS_{y^*}} = -\frac{x_y - x_y^*}{x_{y^*} - x_y^*} \\ &= -\frac{1 - a_y - a_{r_e} r_{e_y} - (a_r + a_{r_e} r_{e_r}) r_y}{1 - a_{y^*}^* - a_{r_e}^* r_{e_{y^*}}^* - (a_{r^*}^* + a_{r_e}^* r_{e_{r^*}}^*) r_{y^*}^*} < 0 \\ \left.\frac{\partial y^*}{\partial y}\right|_{BP} &= -\frac{BP_y}{BP_{y^*}} = \frac{r_{e_y} + r_{e_r} r_y}{r_{e_{y^*}}^* + r_{e_{r^*}}^* r_{y^*}^*} > 0\end{aligned}$$

#### A Fiscal Expansion

$$\begin{aligned}\frac{dy}{dg} &= -\frac{1}{t_x} \frac{r_{e_{y^*}}^* + r_{e_{r^*}}^* r_{y^*}^*}{\Delta_3} > 0 \\ \frac{dy^*}{dg} &= -\frac{1}{t_x} \frac{r_{e_y} + r_{e_r} r_y}{\Delta_3} > 0\end{aligned}$$

$$\text{where } \Delta_3 = \begin{vmatrix} IS_y & IS_{y^*} \\ BP_y & BP_{y^*} \end{vmatrix} > 0.$$

#### Increased Issue of Emission Permits

$$\begin{aligned}\frac{dy}{d\bar{e}} &= \frac{r_{e_e}}{t_x} \frac{\left[1 - a_{y^*}^* - a_{r_e}^* r_{e_{y^*}}^* - (a_{r^*}^* + a_{r_e}^* r_{e_{r^*}}^*) r_{y^*}^*\right] - (r_{e_{y^*}}^* + r_{e_{r^*}}^* r_{y^*}^*) a_{r_e}}{\Delta_3} > 0 \\ \frac{dy^*}{d\bar{e}} &= -\frac{r_{e_e}}{t_x} \frac{1 - a_y - a_r r_y}{\Delta_3} < 0\end{aligned}$$

Curve shifts

$$\begin{aligned}\left.\frac{\partial y}{\partial \bar{e}}\right|_{IS} &= -\frac{IS_{\bar{e}}}{IS_y} = -\frac{r_{e_e}}{r_{e_y} + r_{e_r} r_y - \frac{1 - a_y - a_r r_y}{a_{r_e}}} > 0 \\ \left.\frac{\partial y}{\partial \bar{e}}\right|_{BP} &= -\frac{BP_{\bar{e}}}{BP_y} = -\frac{r_{e_e}}{r_{e_y} + r_{e_r} r_y} > 0\end{aligned}$$

Thus, the IS curve shifts more than the BP curve in the horizontal direction.

#### Heightened Expectations of Exchange Rate Depreciation

$$\begin{aligned}\frac{dy}{d(\hat{x}^{\text{exp}})} &= -\frac{1 - a_{y^*}^* - a_{r_e}^* r_{e_{y^*}}^* - (a_{r^*}^* + a_{r_e}^* r_{e_{r^*}}^*) r_{y^*}^*}{\Delta_3} < 0 \\ \frac{dy^*}{d(\hat{x}^{\text{exp}})} &= \frac{1 - a_y - a_{r_e} r_{e_y} - (a_r + a_{r_e} r_{e_r}) r_y}{\Delta_3} > 0\end{aligned}$$

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