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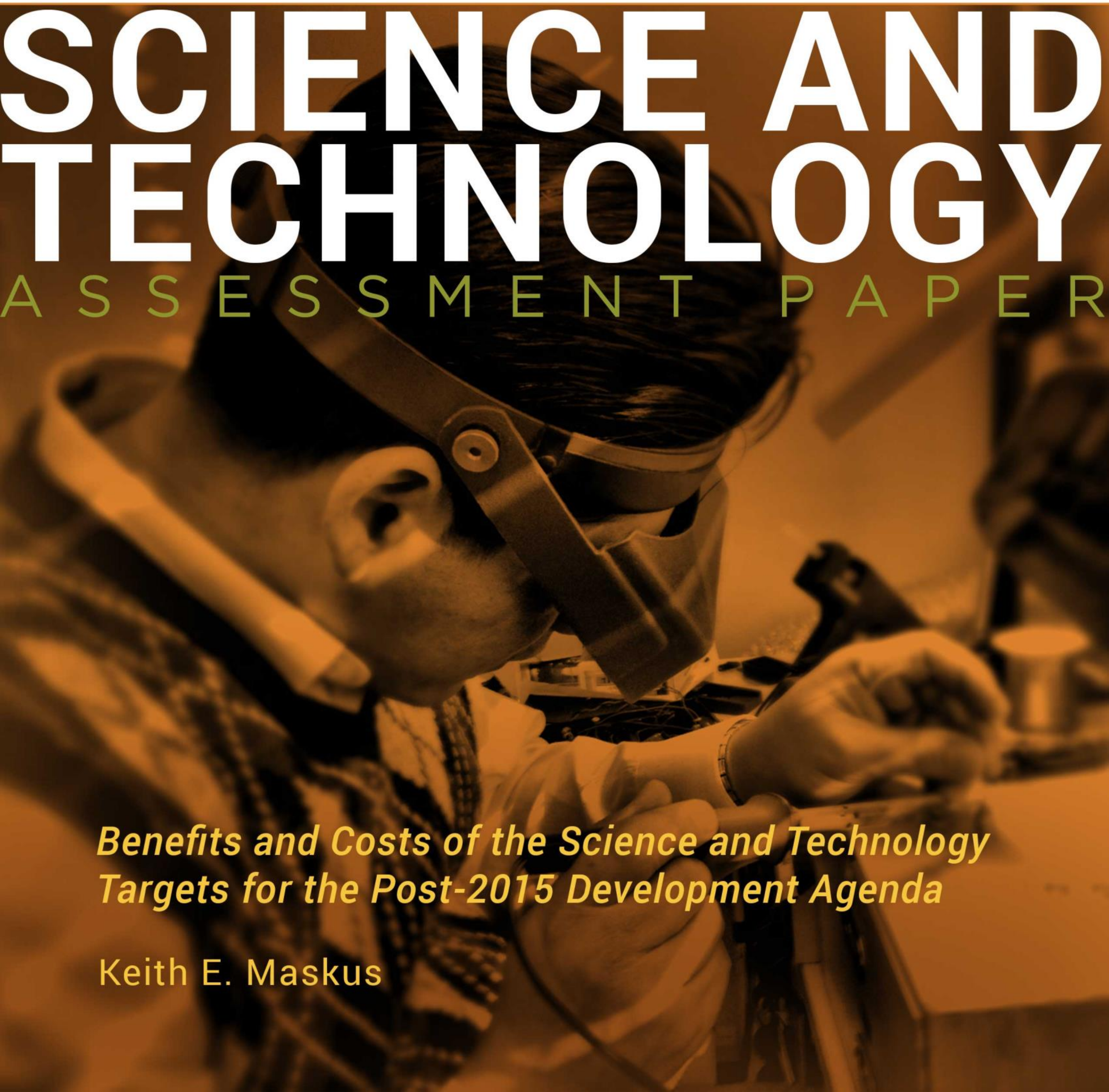

SCIENCE AND TECHNOLOGY

ASSESSMENT PAPER

Benefits and Costs of the Science and Technology Targets for the Post-2015 Development Agenda

Keith E. Maskus

POST-2015 CONSENSUS

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Keith E. Maskus
University of Colorado, Boulder

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Highlights

Regarding technology initiatives, the targets that have the highest benefit-cost ratios are:

- Expand open international circulation of skilled workers by 20% of current skilled migrants within North-South innovation zones. This has a benefit-cost ratio of 21.
- Expand open international circulation of skilled workers by 5% of current skilled migrants within such zones, which has a benefit-cost ratio between 9.0 and 21.

A valuable target within the focus area is:

- Encourage developing countries to increase their ratios of R&D spending to GDP to 0.5%, and emerging countries to raise their ratios to 1.5%, both of which have a global benefit-cost ratio of 2.7 to 3.8.

Overview Table: Benefit and Costs in $ Billions

Target	3% Discount Benefit	Cost	B:C Ratio	5% Discount Benefit	Cost	B:C Ratio
Raise the ratio of R&D spending to GDP among **developing countries** to 0.5% (large innovation spillover case in brackets)	46 (64)	17 (17)	2.7 (3.9)	32 (43)	14 (14)	2.3 (3.2)
Raise the ratio of R&D spending to GDP among **developing countries** to 0.75% (large innovation spillover case in brackets)	101 (141)	36 (36)	2.8 (3.9)	70 (95)	30 (30)	2.4 (3.2)
Raise the ratio of R&D spending to GDP among **emerging countries** to 1.5% (large innovation spillover case in brackets)	347 (486)	129 (128)	2.7 (3.8)	243 (328)	106 (105)	2.3 (3.1)
Raise the ratio of R&D spending to GDP among **emerging countries** to 2.0% (large innovation spillover case in brackets)	882 (1235)	326 (324)	2.7 (3.9)	616 (834)	269 (267)	2.3 (3.1)
Expand open international circulation of skilled workers by 5% of current skilled migrants within North-South innovation zones **LOW SCENARIO**	20	2	9.3	17	2	9.4
Expand open international circulation of skilled workers by 5% of current skilled migrants within North-South innovation zones **MED SCENARIO**	21	2	9.5	17	2	9.7
Expand open international circulation of skilled workers by 5% of current skilled migrants within North-South innovation zones **HIGH SCENARIO**	46	2	21.3	39	2	21.6
Expand open international circulation of skilled workers to 20% of current skilled migrants within North-South innovation zones	180	9	20.8	158	8	21.0

Notes: Benefit-cost ratios are correct to one decimal place, but may not equal the benefit divided by cost, *in this table*, due to rounding. See body of report for exact benefits and costs. Developing countries exclude the poorest and smallest. See Table 2 for classifications of countries into developing and emerging countries. 'North-South Innovation Zones' are explained in greater detail in Section 3 of this paper.

Introduction

In its deliberations regarding development of the Sustainable Development Goals (SDG) for 2015 and beyond, the UN working group has given consideration to various issues that might collectively be termed “science and technology initiatives”. To some degree these issues are horizontal and cut across several goal areas within the SDG documents. For example, the working group’s communication of June 2, 2014 listed technology development or technology transfer objectives within numerous broad goals, including industrialization, sustainable agriculture, and application of green technologies.[1] In general, the working group sees technology as a component of the objective to “strengthen and enhance means of implementation and global partnership for sustainable development”. In this context, access to, and investments in, science and technology (S&T) relevant for economic development can support a variety of objectives, though few of those listed bear any specificity.

The inclusion of S&T as facilitators for defining and achieving SDG is sensible, for access to, and effective implementation of, knowledge and technical information are fundamentally important sources of economic growth arising from structural change and productivity gains (Keller 2004). They are equally central to investments to meet public needs, such as adaptation to climate change, water safety, and public health (Maskus and Okediji, 2014). Thus, technology initiatives speak both to economic development and sustainability, making them a suitable candidate for inclusion in the SDG in some form, whether broad and horizontal or narrowly focused on specific targets.

As noted, most of the cases in which technology is listed in the working documents involve broad aspirations, rather than clearly articulated targets. Here are three examples from the June 2, 2014 statement:

- Increase investment in rural infrastructure, agricultural research, technology development, institutions and capacity building in developing countries to enhance agricultural productive capacity, particularly in countries that are net food importers (p. 17).

- Promote regional and international collaboration on and access to science, technology, innovation, research and knowledge sharing, including through North-South, South-South and triangular cooperation (p. 19).

- Promote transfer and dissemination of clean and environmentally sound technologies to developing countries, including through the possible implementation of a UN global technology facilitation mechanism, and encourage the full use of TRIPs flexibilities (p. 19).

[1] UN Working Group, “Introduction and Proposed Goals and Targets on Sustainable Development for the Post-2015 Development Agenda,” 2 June 2014.

This lack of specificity is unsurprising in light of the subject matter. Technology transfer and investments in research and development (R&D) are largely private decisions made by profit-oriented enterprises, although there are certainly significant expenditures undertaken by public authorities and their grantees. In this context, such words as "promote" and "encourage" seem appropriate in that the primary objective may simply be to improve market and governance conditions to induce firms to disseminate technologies and undertake R&D programs that are more conducive to economic and social development. Similarly, such goals as cooperation to increase collaboration on and access to science and full use of TRIPs flexibilities, while likely to be pro-development, cannot readily be translated into numerical targets for benefit-cost analysis.

For this reason the current paper begins from a situation of limited information: just how might we articulate objectives that both facilitate the broad objectives of the SDG and still be reasonably amenable to numerical analysis? To limit the scope of the project, I have chosen two objectives that are horizontal in nature in that, if achieved, could offer strong facilitation to technology diffusion, access to knowledge, and growth of local technological capacities in developing countries. Each of them involves costs as well, raising the question of whether the net benefits are likely to be sufficient to incorporate them into implementation of the SDG.

The first objective is to increase the ratio of R&D spending over GDP to specific targets in developing and emerging economies. This idea in fact is mentioned in the working group document, though without mentioning targets:

- Promote industrial research, development and innovation, including raising the ratio of R&D workers per one million people by x% and the share of R&D spending in GDP by y% (p. 10).

To put this idea into analytical terms, I posit that policies might be undertaken to expand the R&D/GDP ratio, above the rate at which it has been rising historically, to either 0.5% or 0.75% in developing nations, and either 1.5% or 2.0% in emerging nations, by 2030. The policies involve expanding R&D tax credits to achieve 50% of the incremental R&D and direct government expenditures to accomplish the other 50%.

Increased R&D by itself is not an economic benefit, rather it is a means to achieving technological ends. Here, economic benefits include spillover learning benefits from expanded R&D investments and gains from additional innovation that may be induced in the economy. Costs include efficiency losses from attracting resources from other uses, financing costs, and administrative and compliance costs. The calculations suggest that, in most cases, the benefits from these policies exceed the costs but the benefit-cost ratio rarely exceeds about 1.4 unless there are implausibly high estimates of induced-innovation gains in the future.

The second objective is to establish 10-year visas permitting free mobility of skilled (technical and managerial) labor among participating "innovation zones" in an effort to optimize technology diffusion, efficiency, and learning among enterprises within such zones. Recent and emerging evidence points to the importance of labor mobility in transferring technical information across borders and adapting it to local uses. To be achieved, this objective likely would require the negotiation of plurilateral zones under the General Agreement on Trade in Services (GATS) at the World Trade organization (WTO), a difficult prospect.

Quantification of the costs and benefits of such zones is particularly speculative, given the scarcity of relevant studies of what would be a new policy initiative. To implement the idea I consider potential effects within two suggestive zones: one that is North-South in orientation and one that is South-South. Both focus on such arrangements within the Western Hemisphere, with the North comprising Canada and the United States and the South comprising the rest of the Americas. Here the suggestion is far more positive: the benefit-cost ratio of a tightly limited North-North agreement exceeds 13 under conservative parameter estimates. The bulk of this net gain comes from large income increases for the skilled workers and associated remittances. Even netting out these impacts, however, the benefit-cost ratio within the Hemisphere is around four. An innovation zone among the developing economies would result in far smaller flows but still would generate a benefit-cost ratio over seven.

Benefits and Costs of National R&D Targets

Background and Literature

It is often argued that expanding national investments in R&D, whether by public authorities or (perhaps more so) private enterprises, is an important impetus for economic development and growth for several reasons (Romer 1990, Griffith 2000). Such investments generate new and lower-cost ways of producing goods and services, facilitate innovation of new products, and can support profits of innovative firms, which translate into higher real wages and human capital. Consumer gains through higher quality and new product varieties can be especially significant sources of welfare growth (Aghion and Howitt 1998). Firms that have R&D laboratories are more likely to experience productivity gains from acquiring and absorbing advanced international technologies (Keller 2004).

While all of those factors are important they are not enough to justify government intervention to subsidize R&D, for the benefits may accrue to those undertaking the private investments. Rather, the basic case for government support rests on market failure: private firms are not able to fully appropriate the productivity returns to R&D investments. Instead, some of the increased knowledge and know-how spill over into higher productivity on the part of other firms, which may not have to pay for these gains. Similarly, because it is difficult to exclude agents from using knowledge, there may be consumer gains that cannot be captured by the originators.

Thus, many studies over the decades have demonstrated that the social returns to R&D, accounting for these spillovers, are higher than the private returns, implying that the market by itself supports a sub-optimal level of investment and that consequent growth is stunted (Griffith 2000). This issue is clearest in the case of basic scientific research, which may support numerous market applications but have little direct economic return (Nelson 2005). These problems offer the basic justification for national public intervention. Moreover, some of these external gains cross borders, meaning that the gains to the investing economy are lower than global gains (Keller 2004, Eaton and Kortum 1996). In this sense, knowledge is a global public good, especially where it supports innovation in technologies relevant for meeting social needs, implying that some forms of international support or coordination are required for optimal provision (Maskus 2006).

Presumably, the interest of the UN working group in raising the ratio of R&D expenditures in GDP in developing and emerging economies reflects the view that such investments generate sufficient spillover gains as to justify any associated costs of policy interventions. There is little doubt that at least among the technologically advanced OECD economies, R&D investments (both public and private) have supported productivity spillovers and growth, though the causal relationships between R&D and economic growth are complex and difficult to sort out (Rodriguez-Pose and Crescenzi 2006, Westmore 2013). Public policy, whether via direct expenditures on research, R&D tax credits, accelerators, commercialization support, financing guarantees, or other elements have played a stimulating role, though the record is far from uniform over time and across countries (Griffith 2000). Indeed, studies that assess the effectiveness of such policies tell a mixed story. Bloom et al (2002) find through panel econometric analysis that R&D tax credits in 19 OECD countries over 1979-97 were effective, in that a 10% fall in the cost of R&D stimulated nearly a 10% rise in expenditures in the long run. Gonzalez and Pazo (2008) find that public subsidies to R&D do expand investments by small and medium-sized enterprises (SMEs) and that there is little evidence that public R&D crowds out the induced private expenditure.[2] Similarly, a meta-analysis by Kohler et al (2012) found that tax incentives among OECD countries in recent years have generally stimulated additional R&D, though the type of incentive mattered for the ultimate response.

As Kohler et al point out, however, studies of the ultimate impacts of the additional R&D on such performance variables as spillovers, productivity and competitiveness are scarce, even within the OECD. Some projects find a positive impact on the probability that an incentive recipient will introduce a new process or product, but the evidence for productivity gains is limited. In this context, available welfare analyses of specific R&D support policies, which attempt to set spillover gains against program costs, are rather reserved. Lester (2012), for example, computes that a basic R&D tax credit in Canada for smaller firms generates a net benefit but extended credits and direct assistance incur costs greater than welfare gains. Russo (2004) finds that the Canadian incremental R&D tax credit supports substantial net benefits but that comprehensive credits do not. In a different vein, Goolsbee (1998) speculates, on the basis of back-of-the-envelope calculations, that government funding of R&D in the United States has in large part just pushed up the wages of scientists and engineers, who are in inelastic supply, without achieving much innovation. I have been unable to find studies of these basic policy questions in any developing or emerging countries.

[2] Aerts and Schmidt (2008) report similar results for Germany and Flanders.

Current Situation

To assess the policies that may be required to raise R&D/GDP ratios it is important first to note where those ratios are and how much they have grown in recent years. Thus, I present in Table 1 basic data, taken from the World Bank's World Development Indicators (WDI), showing the share of R&D in GDP, and growth in that ratio, in a sample of developing (DCs), emerging (ECs), and more developed (MDCs) countries. The DC sample is somewhat small due to limited data availability but it does cover the major economies as noted in Table 2.[3] The notes to that table explain the categorization I have chosen. Note that I exclude the countries defined by the World Bank to be low-income, both because very few of them exhibit R&D data and because their current ratios are so low there is virtually no likelihood that they would rise to significant levels within 15 years.[4]

As shown in Table 1, the most recent GNI-weighted R&D ratio among the developing countries is 0.19, with considerable variability among them. The ratio grew about 3.7% annually from 2000-2010, implying that recent socioeconomic conditions have supported notable growth in R&D expenditures relative to GDP. If that growth were to continue on a linear path, by 2030 the group of DCs would achieve a ratio of 0.3. Among the emerging countries, excluding China, the most recent weighted R&D ratio is 0.83, which has grown at approximately 2.8% per year. Again, it is noteworthy that existing conditions incentivize this relatively rapid investment growth. If that growth rate continues, the ECs as a group (without China) would get to a ratio of 1.18 by 2030.

As might be expected, China is a special case. By itself, the current R&D ratio is 1.69, far higher than the other ECs and higher than many nations in the developed sample. China's ratio has been rising at 9.5% per year, remarkable in light of the rapid GDP growth it has accompanied. Were that growth to continue, China's ratio would reach 4.1 in 2030. Finally, the group of developed economies displays R&D ratios ranging from 1.25 to 4.54, with a weighted average of 2.61. It is not surprising that this ratio has grown least rapidly within this group, at 1.3% per year, since they are closest to the technological frontier, a situation that tends to diminish returns to R&D and thereby reduce relative incentives to invest.

Based on this data review the following factors seem relevant in defining R&D targets for analysis. First, it seems clear that the R&D ratio will continue to rise among these country groups and additional policy incentives are not needed to sustain that growth. Thus, I take as a baseline the notion that each group's R&D/GDP ratio will rise at its historical trend and naturally achieve the "2030 expected ratio" levels within 15 years. It follows that the cost-benefit analysis should focus on attempts to raise the ratios incrementally above these levels, with policies taken to raise the growth rate above its existing trend. Second, for both DCs and ECs it makes sense to define a modest objective and an ambitious objective for the R&D ratio. Thus, modest objectives would be to increase the 2030 ratio among DCs from 0.30 to 0.50 (along a linear path) and an ambitious goal would be to raise it from 0.30 to

[3] The OECD offers more comprehensive data, but only for its members and a few major emerging economies. For consistency I use the WDI figures. I excluded small island countries and predominantly oil-based economies.
[4] This exclusion also biases the results in favor of finding net benefits for R&D policies, since it is unlikely that in very poor countries subsidies to R&D would be sufficiently effective to overcome the fiscal costs.

0.75. The corresponding growth rates of the ratio would be 11.0% and 19.7% respectively per year. The analogous targets for the ECs would be ratios of 1.5% and 2.0% of GDP, with corresponding growth rates of 5.4 and 9.4% per annum. These are substantial increases and presumably would require more than marginal changes in incentive packages.

Third, there seems little reason to hold China and the developed countries to additional growth in their R&D ratios. China seems quite likely to achieve an R&D ratio in excess of 3.5 on its current growth path. Thus, there seems little point in performing an incremental benefit-cost analysis since China presumably need not alter its policy incentives; in fact it could scale them back. Put differently, if we posited a target ratio of 3.0 by 2030 for China, that country could reduce its annual investment growth rate and still attain it. Similarly, the developed economies as a group are likely to achieve a ratio of at least 3.5 without further interventions, which would be historically high. It does not make much sense to ask them for further increases within the context of the SDG program. Thus, I focus the benefit-cost analysis here on the targets noted for the DCs and ECs.

Model and Assumptions

An initial, and very difficult question, is just how countries could use policy to raise R&D spending relative to GDP. There are a great many policy instruments one could imagine, including, among others, direct research grants, various tax advantages, subsidies to locate in R&D clusters, commercialization support, and reduced patent fees. This project would be unwieldy if it tried either to consider (or rank) this range of interventions or to attempt an analysis of the interactions among them, especially in light of limited data.

Rather, I focus on a combination of two policies, which I assume operate independently. The two policies come from considering the breakdown of R&D into government research expenditures (including higher education) and business-enterprise expenditures. This breakdown is available for a small number of DCs and ECs using World Bank and OECD data. In both groups the breakdown is consistent: essentially 50% of R&D expenditures are public and 50% are made by business enterprises. In that context, I posit that any increase in R&D toward an annual target is split evenly between public and private sources.

For purposes of computation I adapt a partial-equilibrium model of R&D costs and benefits from Lester (2012), which was developed for Canadian policy. I assume the incremental policy initiatives begin in 2015 and have effects in 2016 through 2030, for a 15-year horizon. Specifically, I compute for each year from 2016 to 2030 a target level of real R&D expenditures that would achieve the requisite linear growth in the R&D/GDP ratio for given constant growth rates in real GDP. These GDP growth rates are set at 5% for DCs and 3.5% for ECs, which seem reasonable for the next 15-year period.[5] This calculation selects an annual R&D target expenditure for the group, which is split between expanded government research spending and enterprise investments. The associated policies then are, first, direct government grants to R&D and, second, an R&D tax credit sufficient to achieve the enterprise target. Again, these computations are for investments above what would be anticipated under existing circumstances, with those growth rates held constant

[5] Selection of GDP growth rates has little impact on benefit-cost ratios.

over the period. Finally, I assume in the basic scenarios that the policies envisioned work equally across countries within the group and that no program impacts spill over into effects in other country groups. In subsequent calculations I do account for cross-border global externalities.

The model is simple and presented in Appendix 1. In essence, it identifies and computes the following benefits and costs, keeping in mind that achieving the R&D targets is not, in itself, a welfare benefit. On the cost side are three factors. First is the efficiency loss imposed on the economy by subsidizing the use of capital and skilled labor into R&D activities that would not otherwise exist. Here, the effect of expenditures and subsidization is to raise the input costs facing those activities that do not receive an increase in public support. Second is the marginal efficiency burden of the fiscal cost of paying for the increased public expenditures and the lost tax revenues of the tax credit, accounting for the spillover changes in GDP. Third is the cost to the government of administering the programs and to enterprises of complying with it. I assume these various costs last during the 15-year life of the program but no further.

There are essentially two domestic benefits of public subsidies to R&D. One is the spillover productivity gains to the economy, which depend on how much take-up there is in the program and the extent of output growth in firms benefiting from the externality. I assume that these productivity-related external gains exist through the length of the program but then revert to zero because there is no further incremental R&D created. A second is the possibility that these spillovers will generate additional domestic innovation (as opposed to incorporating subsidized technologies into production) from reverse engineering, demonstration effects, and learning by doing in laboratories, resulting in further cost reductions. Since these dynamic gains can continue in the longer term, I permit them to continue for an additional ten years beyond the program.

The spillovers mentioned in the prior paragraph relate to external productivity impacts on the supply side within investing countries. Expanded R&D expenditures have the additional important benefit that new knowledge supports external consumer gains in the home economy, as noted above. Moreover, these user benefits can cross borders in various embodied and disembodied forms, procuring greater consumer gains and lower production costs in foreign locations. Knowledge is inherently a public good in that it may be used by agents around the world, multiplying the domestic social gains from R&D investments. While such usage spillovers exist for private R&D (Eaton and Kortum 1996), they arise especially from basic research funded publicly in the OECD countries, such as investigations into new agricultural varieties, medicines, biotechnologies, computer science, laser technologies and astrophysical research (Pardy and Alston 2010, Maskus 2006). The extent to which such international gains exist as pure external benefits is much debated in the literature, though there is little solid evidence to go on. In part, this is because they are heavily dependent on context, for spillovers into global use may be effectively impeded by distance, inadequate economic and social infrastructure, poor absorptive capacities, and intellectual property rights. Moreover, studies to date have focused on diffusion of knowledge developed in industrially advanced countries, rather than on that generated in emerging and developing countries. Nevertheless, greater R&D

expenditures in such countries should support some increase in global usage gains and I include a rough calculation below.

The table in Appendix 1 shows the parameter values chosen for the benefit-cost analysis. An initial selection is the target levels of incremental real (PPP-adjusted) R&D expenditures for each year of the program that are required to reach the target R&D/GDP ratio by 2030. These are computed from the information in Table 1 for the DC and EC groups. To illustrate, for the group of DCs the targeted additional R&D would rise from $1.2 billion in 2016 to $30 billion in 2030 under the scenario of ambitious expenditure growth. For the ECs the corresponding rise would be from $11.8 billion to $257.5 billion. I input these annual targets into the model and compute the resulting benefits and costs of attaining them through tax credits and direct expenditures.

The first key parameter is the direct spillover from the incremental R&D investments into lower costs and higher productivity throughout the economy. The estimate for Canada used in Lester (2012), taken from Parson and Phillips (2007), is that among enterprises the spillover rate is 0.56, or 56 cents worth of external gains per dollar of expenditure. This estimate is consistent with those in other OECD countries (McFetridge 2011). For direct public assistance Lester employs a spillover rate of 0.76. There is very little information on such parameters in the developing world, though one might imagine they are somewhat larger due to weaker intellectual property protection. Thus, I use two values (0.6 and 0.8) for the spillover rate from the R&D tax credit and one value (0.8) for that from direct public R&D. The ultimate level of spillover gains depends also on the price elasticity of R&D, which I maintain constant at 1.0, consistent with the literature.

Next is the effective subsidization of R&D from the policies. In Lester (2012) the subsidy rate from R&D tax credit is assumed to be 0.4 for small firms and 0.2 for large firms. Lacking information on the size distribution of firms in DCs and ECs I assume an overall subsidy rate ranging from 0.2 and 0.4. Since public expenditures go directly into R&D, I assume a subsidization rate of 1.0 for that half of the program. Marginal compliance and administrative costs are averages of those for large and small firms in Lester (2012) and I keep these fixed throughout. Where the approach here differs from Lester's model is that he calibrates fixed compliance costs and fixed administrative costs to entry and exit of firms after the tax credit is imposed. I do not have sufficient information on the number and distribution of firms to perform this calculation and therefore take a simple parameter, multiplicative in target R&D, to represent both types of fixed costs. This parameter varies between 0.005 and 0.01.

The marginal excess burden (efficiency loss) of taxes is a complex subject and a full treatment would permit the associated function to depend on the types of taxes used to pay for the program and how distortionary they are between sectors and types of income. Again, failing that detailed information, I follow Lester (2012), who uses the parameter 0.26, based on Canadian data, varying the parameter here between 0.2 and 0.3. Finally, the marginal effective tax rate, required to pay for net fiscal costs of the program, is also a complex calculation that cannot be performed here at the group level. Lester (2012) uses an estimate for Canada of 0.264 and I essentially follow his lead, varying the tax rate from 0.2 to 0.25.

The final parameter choices capture the welfare gains from induced innovation, which itself generates spillovers going forward in addition to those coming from the targeted R&D. As described above, I permit two kinds of external innovation gains, reflected in the calculations. First, in the basic scenarios I permit simply an induced-innovation spillover into domestic productivity. Second, in subsequent calculations I add the possibility of domestic and international external user gains, which should be markedly larger to the extent higher R&D spending produces embodied knowledge that is both useful and readily acquired at low cost. The reason for this bifurcation is to highlight the difference between basic domestic productivity spillovers and broader international consumer gains.

Whether such incremental innovation by third parties, induced by R&D support to participants, exists in DCs and ECs is a controversial question, though it is frequently discussed in the literature as an active possibility (He and Maskus 2012). As noted above, there are few studies of these "additionality benefits" of R&D subsidies, though conventional wisdom suggests they exist (Kohler et al 2012). I could find no empirical estimates of the basic process in DCs or ECs. Thus, regarding the primary domestic productivity spillover, I assume a wide range, from one percent to four percent of target R&D, and consider scenarios where this additional gain cuts out in year 15 or continues through year 25.

Determining what might be appropriate usage spillover rates is difficult, given the lack of relevant evidence. I start by noting a recent study in the UK showing that R&D (publicly funded and private expenditures combined) in cardiovascular treatments resulted in a net domestic spillover gain of 39%, meaning that each dollar of investment procured $1.39 in social benefits (Health Economics Research Group et al 2008). There was a 37% external benefit from R&D in mental health interventions. These benefits came from improved health status, gains in GDP from healthier workers, and other spillover productivity gains. Of course, the incremental R&D generated in DCs and ECs under consideration in the current analysis would not all be spent on high-payoff medical research. This is because such innovations are not yet within the comparative advantage of DCs and ECs and because it would make little sense to design the R&D subsidies with this sectorial focus in mind.[6] Moreover, it seems likely that R&D programs in DCs and ECs would not translate as efficiently into spillover benefits as they do in the UK.

For all these reasons, I consider a range of external domestic gains of 15% and 25%. Unfortunately, the UK study did not consider any international spillover benefits and these should be included in an inclusive computation. I therefore add 1/5 (3% and 5%, respectively) of the domestic gains to capture global effects, resulting in induced innovation benefits of 18% and 30%.[7] Moreover, consistent with the UK study, I assume

[6] Evaluation of the potential for gains from broader development goals is left to other papers that focus on public health and the environment.

[7] These international impacts seem reasonably in light of similar ranges of TFP gains in developing countries from importing capital goods and intermediate goods, as analyzed by Coe et al (1997).

that there is a seven-year lag between the time R&D is spent and the associated spillover consumer gains, meaning that the latter exist from year 8 through year 32 from program launch. However, in principle these gains would last even longer, since goods and services produced by the R&D can be enjoyed by consumers as long as they are on the market. To approximate this impact I permit consumer external gains to last for 40 years from program inception. I emphasize that there is considerable uncertainty in these parameter and duration selections and results should be treated with caution. In my view, these supplemental assumptions likely bias the computations toward finding high benefit-cost ratios. Overall, this logic suggests that the basic cases (no usage spillovers) and the extended cases (significant usage effects) surround the true welfare impacts.

Results

Tables 3a and 3b present the calculations of benefits and costs, discounted to net present value (NPV) for DCs, using this model and parameter values. Columns are labeled by number to indicate various scenarios in the partial-equilibrium setup. Table 3a is the "modest" target scenario, generating a growth of the R&D ratio to 0.5 percent of GDP by 2030. The first column contains the results for a benchmark set of parameter values. Program benefits, discounted at 3%, amount to $18.7 billion while costs sum to $17.2 billion, yielding a B/C ratio of 1.09 for the case where induced innovation ends with the program (i.e., the 15-year period). Adding 10 more years of the strictly domestic induced innovation gains at 1% would raise the B/C ratio to 1.13. Note that discounting by 5% reduces the NPV of both benefits and costs but has little impact on the B/C ratio.

Columns 2 through 7 consider changes in parameters for the basic scenarios, some that raise benefits and some that raise costs.[8] For example, increasing the private spillover rate from 0.6 to 0.8 raises the B/C ratio marginally from 1.09 to 1.12 (column 2), while raising the marginal excess burden of taxes actually reduces the B-C ratio to below 1.0 (column 3). The most favorable primary scenarios are in columns 5 through 7, where the induced innovation benefit rate is raised to 0.04. In these case the B/C ratio is around 1.2 over 15 years and 1.4 over 25 years.

Table 3b presents the computations for the more ambitious target of 0.75% of GDP. This case increases both program benefits and costs but does not change the basic message: the B/C ratio ranges from 0.9 to 1.4 for the group of developing countries when considering just domestic effects.

Tables 4a and 4b repeat this analysis for the group of emerging countries. Since the model and parameters used are the same it is not surprising that the primary difference is just in the much larger scale of benefits and costs. However, the conclusion about benefits versus costs remains the same: the ratio peaks at 1.41, depending on circumstances.

To summarize the basic computations, expanding the R&D share in GDP above and beyond what it is likely to attain automatically (i.e., at recent growth rates) both generates welfare benefits and incurs economic and budgetary costs. Thus, while the most positive cases do

[8] I defer discussion of the final two columns to after presentation of the basic scenarios.

support a ratio of domestic benefits to costs solidly above unity, the program does not seem to rise beyond this range. If, therefore, a primary goal of programs to raise the relative share of R&D in the DCs and ECs is to expand domestic productivity there do not seem be sufficiently large net benefits available to qualify as strong or phenomenal investments. Such countries would be better advised to invest in human capital and governance to establish solid frameworks within which knowledge spillovers from access to international technologies are optimized.

This pessimistic conclusion is offset considerably, however, if there are large usage spillovers, as shown in the final two columns of Tables 3a through 4b. In Table 3a, for example, column 9 shows that over 40 years the additional domestic and international consumer gains from an 18% spillover rate would procure discounted program benefits of between $32 billion and $46 billion. At the same time, program costs would not change much because they are modeled to end in year 15. These assumptions then generate notably larger B/C ratios of between 2.3 and 2.7. With the larger 30% rate the B/C ratio would rise to between 3.2 and 3.9, marking the program as potentially quite successful. In Table 4b, where the large emerging countries would expand their R&D ratios aggressively to 2% of GDP by 2030, the available benefits would mount to between $882 billion and $1.235 trillion, albeit with similar B/C ratios.

To conclude, how one assesses the idea of policies to generate higher R&D ratios in developing and emerging countries depends a great deal on her views of the program goals and likely outcomes. In discussing science and technology as a sustainable development goal, the UN seems to emphasize expanding the access of poor countries to international knowledge. In this context the basic computations seem more relevant, though they may understate actual benefits somewhat. Growing the intensity of domestic R&D expenditures would not appear to be an objective with a large net payoff. However, if observers think such programs could procure significant external consumer gains across borders the extended scenarios would be more relevant, and R&D programs could accomplish notable net benefits.

Benefits and Costs of Expanded International Skilled-Labor Mobility

Many international economists argue that the actions that would most increase global efficiency and welfare, while raising incomes in the developing world, are significant relaxations of barriers to cross-border immigration and emigration, including temporary movements of labor (van der Mensbrugghe and Roland-Holst 2009, Walmsley and Winters 2005). In the words of Clemens (2011), the world is leaving "trillion dollar bills on the sidewalk". Indeed, the simulated welfare gains from removing international mobility barriers, as calculated by various simulation models, are staggering, ranging from 67% to 147% of global GDP (Iregui 2005, Moses and Letnes 2004, Klein and Ventura 2007, Hamilton and Whalley 1984). In comparison, the potential gains from removing all remaining barriers to merchandise trade (post-WTO foundation) amount to perhaps one percent of world GDP, with the same magnitude for eliminating barriers to capital flows

(Anderson and Martin 2005, Hertel and Keeney 2006, Gourinchas and Jeanne 2006). In economic terms it is a wonder that global negotiators are not focusing far more on mobility issues than on resurrecting the largely moribund Doha Round.

The reason for this large difference in welfare impacts is easily understood from the analysis in Figure 1, first developed by Bhagwati (1984). Suppose there are two countries or regions in the world, a low-wage source (S) of potential migrants and a high-wage destination (D). The vertical axes depict the real wages (equal to labor productivity) in the source (left-hand side) and the destination (right-hand side). The length of the horizontal axis measures the sum of the labor forces, with the source labor supply read from origin O_s and that in destination read from origin O_d. Demands for labor in the regions are downward-sloping, as shown. Supposing that the initial world allocation of labor is at point L^0, real wages are then w_s^0 and w_d^0. A complete elimination of migration barriers would equalize wages where the labor-demand curves intersect and significantly reallocate the global labor supply. However, the figure depicts a partial migration, from L^0 to L^1, which would raise the source wage and lower the destination wage, with the extent depending on elasticities of labor demand.

Consider a basic welfare calculation from this partial mobility. Those who move would see their real wage rise to w_d^1 and would enjoy a large real income gain of area A + B + H. The workers who do not migrate would gain real income of area C but owners of other factors (capital and land) would suffer a decline in income of area C + B due to lower productivity as workers move out. In the destination country, workers lose real income in the area G but other factors gain productivity in the area G + E. In brief, the destination gains area E on net, movers gain area A + B + H, and the source country loses C + B. The net global welfare rise is area A + H + E, most of which goes to the laborers who move abroad. This is not a windfall, however, for those movers become as productive as workers in the destination, meaning that the global welfare increase arises from an expansion of global productivity, which migration barriers were preventing. The essential reason for large gains is now clear: labor mobility generates "rectangles" of productivity rise, which are far larger than the "triangles" available from trade liberalization.

More perspective is required on this basic story. First, whether the source country actually becomes worse off depends on decisions by out-movers to remit some of their income gains. Any remittances that exceed area B would generate net income gains in the source, though it would not affect overall welfare calculations since this would be a transfer from movers to stayers.[9] Second, this analysis assumes that movers are inherently as productive as workers in D, meaning that the two groups are perfect substitutes in the labor market. It is possible, of course, that movers are inherently less productive, in which case the true labor-demand curve in D lies below the one shown and the gain shrinks. I account for these possibilities in the analysis below.

[9] Whether the income gains to movers should be assigned to S or D is more a philosophical than an economic question, even though the productivity expansion "resides" in D. I sidestep this issue in the welfare calculations below by breaking out movers separately.

Third, it is possible that labor movements generate certain welfare externalities in S and D that need to be considered. Note that the wage changes *per se* are not relevant for welfare; these are pecuniary externalities akin to product-price changes when supply shifts in any economy. However, there are two kinds of externalities discussed in the literature, particularly as regards mobility of skilled or highly educated labor. Fiscal externalities refer to the possibility that public investments in the education of workers in S are lost when they move abroad and that these workers' departure diminishes the remaining tax base. Productivity externalities refer to the possibility that the presence of technically skilled workers in an economy may generate more efficiency in other workers and firms through innovation, learning, and the attraction of high-technology FDI, as discussed in the prior section.

The extent to which these impacts exist is much debated, but little answered, in the empirical literature. They are at the heart of concerns about "brain drain," an old issue in economic development. Certainly policymakers in many developing countries often claim that the out-migration of highly skilled professionals is costly. For example, a member of Mexico's National Council of Science and Technology, noting that "…the number of Mexican professionals living abroad in the last few years grew by 153 per cent, from 411,000 to 1.3 million" claimed that this brain drain amounts to a transfer of $6 billion per year northward.[10] Economic analysis is far more nuanced, however, as will be discussed further below.

A final observation is that the large global welfare gains noted above are computed in an environment of complete labor mobility, which would involve a massive movement of labor, up to 99 percent of the workers in poor countries (Moses and Letnes 2004, Klein and Ventura 2007). This is obviously impossible, both in political and economic terms, making it more appropriate to consider partial movements, with far smaller gains. These impacts are still significant, however. For example, a 7% net emigration rate out of source countries might generate a 10% gain in global output (Klein and Ventura 2007), while a 2% migration might achieve a 2.3% growth in world GDP. This is the spirit in which the computations below are made. Two important differences arise, however. First, I focus on mobility of managerial and technical workers (MTW), rather than undifferentiated labor. Second, I consider the impacts of temporary (though long-lasting) visas that permit free circulation among countries in a cooperative arrangement, rather than full emigration.

Current Situation

It is impossible to find consistent and systematic data on international flows of skilled managerial and technical workers, particularly on a bilateral basis. Thus, I use the limited available evidence to build a bilateral matrix of stocks of such migrants within the Western Hemisphere, the area on which this analysis is focused, using this matrix as a building block for an assessment of changes in flows.

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[10] See "Mexico's brain drain to U.S. 'a phenomenal loss'", SanDiegoRed.com, 30 June 2014, at http://www.sandiegored.com/noticias/21150/Mexico-s-brain-drain-to-U-S-a-phenomenal-loss/.

The initial step is to use the database put together by Docquier, Lohest and Marfouk (2007; hereafter DLM) to analyze brain drain (BD).[11] These figures, currently available only for census years 1990 and 2000, list for all source countries estimates of the stocks of educated labor (those with at least some tertiary education) that were born in those sources, residing legally in each OECD economy, including Mexico.[12] That is, the database estimates the stocks of foreign-born immigrants and permanent residents, from each origin, with higher education. From this database I calculate such stocks in 2000 for the following sources: Argentina (ARG), Brazil (BRA), Chile (CHL), Mexico (MEX), Canada (CAN), and the United States (USA), along with aggregates for Central America (CAM), the Caribbean (CAR), and the rest of South America (SAM). Note that there are two-way stocks, as educated workers move not only from low-income countries to high-income countries but also in the opposite directions.

Because only Canada, Mexico and the United States are destinations in the data, I made assumptions about what relative migration would look like in other directions, based on distance and the share of tertiary-educated workers (taken from the World Bank's World Development Indicators (WDI)) in the source nations. For example, the proportion of such workers from the Caribbean to Central America was taken to be 50% of that from the Caribbean to Mexico.[13] This procedure enabled computation of bilateral stocks of tertiary migrants in 2000. However, not all tertiary-educated workers are managerial and technical workers (MTW). Thus, I use estimates of the share of MTW in tertiary-educated workers in each source, ranging from 0.1 (Caribbean and Central America) to 0.5 (Canada and the US) to scale the bilateral stocks to MTW units.

To update these estimates to 2010 I incorporated data from the United Nations on the bilateral stocks of foreign-born legal migrants.[14] These figures refer to all migrants, regardless of educational status. Applying 2000 bilateral shares of tertiary education among migrants, and the proportion of MTW, I then computed 2010 bilateral migrant stocks. The estimates are provided in Tables 5a (2000) and 5b (2010), which may be read from left to right to note source to destination. Note first that for the aggregated areas the intra-area migrant stocks are positive, since people do move from, say, Ecuador to Colombia. Next, it is no surprise that Canada and, especially, the United States, are large net destination countries. By these calculations the US hosted over 1.6 million MTW in 2000, which grew to over 1.9 million in 2010. The Caribbean sends large numbers of skilled workers to Canada and the United States but relatively few to other Latin American locations. There were nearly 705,000 in-migrants from Mexico in the United States in 2010, making Mexico the largest source. Among the emerging regions, Mexico and Argentina absorb the most MTW workers. It is interesting that the US supplies by far the largest volume of such skilled workers to Mexico, pointing out the two-way nature of this trade. There are also proximity effects: Chile is the largest source of Argentine in-migrants.

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[11] Available at http://www.abdeslammarfouk.com/dlm-database.html.
[12] All data used here refer to legal migration.
[13] Details of such assumptions are available on request.
[14] United Nations, Population Division, Department of Economic and Social Affairs, *Trends in International Migrant Stock: Migrants by Destination and Origin, 2010*, at http://esa.un.org/MigOrigin/.

Perhaps surprisingly, Brazil is the smallest gross recipient of in-migrants despite its large economy.[15]

To see if specific countries or regions are net source or destination locations, simply compare the final column with the bottom row. As would be expected, CAR, MEX, CAM, BRA, CHL and SAM are net suppliers of skilled workers and the US is a large net absorber. Canada sends more MTW abroad than it brings in but that is entirely due to its large presence in the US; it is certainly a net migration destination for the emerging economies. An especially interesting case is Argentina, which in the aggregate is a small net absorber but is a net supplier to the US and Canada.

Innovation Zones: The Idea

Compared to the difficulty of figuring out what policies might actually raise R&D in the prior analysis, the policy ideas here are straightforward, if perhaps based on poor measurements. Specifically, I consider a joint decision by the countries in Table 5b to increase their availability of work visas by particular percentages of their total in-migrant MTW stocks in 2010, with the visas available to eligible skilled workers from anywhere among participant nations. This is the essential idea of an "innovation zone" in which visa-endowed workers would be permitted to circulate freely and work for a lengthy period, say 10 years, among countries in the zone. Workers wishing to get such a visa must demonstrate that they have appropriate academic and/or experiential credentials and an offer of an employed position, for a minimum period, in one of a designated set of management or scientific and technical fields or that a recognized organization (e.g., a corporation or university) sponsors them for this treatment. Each country would decide whether it wishes to extend particular visas for longer periods but could not reduce the number issued going forward. Presumably, visa grantees would be permitted to bring immediate family members with them in order to make such circulation attractive.

To my knowledge there are no full experiments in actual immigration policy of this kind, though the EU does permit largely free circulation of labor. The closest instance is the special policy established in NAFTA for granting visas to business professionals wishing to work in Canada, the US, or Mexico.[16] The US created a new entry class called the TN ("Trade NAFTA") visa, under which qualified Canadian and Mexican business professionals in more than 60 occupational categories could enter the country (with their dependents) if they demonstrate a position offer. The entry is valid for up to three years and may be renewed at the discretion of US authorities. Mexican and Canadian authorities have implemented similar programs, which seem to be somewhat more restrictive. In essence, TN visas are supplements to H1-B visas (those issued for specialized occupations) but established preferentially within NAFTA. For comparison purposes in 2012 the US issued

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[15] This fact stems directly from the UN data, which show Brazil similarly to be a small destination for labor in general. While I have doubts about these figures I have decided to retain them because the estimated stocks seem conservative and therefore will not bias upwards the calculations of benefits and costs. A further reason for using conservative estimates is that the visa policies I consider are really about changes in flows (that is, labor mobility) rather than additions to stocks (actual change in migration and perhaps citizenship) and the implied mobility changes are in line with actual (policy-restricted) visa quantities.

[16] North American Free Trade Agreement, Chapter 16: Temporary Entry for Business Persons.

136,000 H1-B visas and 75,000 TN visas.[17] Note that while this program is similar to an innovation zone it differs in two key respects. First, the TN visas are for a broad swath of professionals, rather than focused on technically oriented skilled workers. Second, the visas issued are solely for working in the issuing country rather than permitting free circulation among positions within NAFTA. Unfortunately, no economic studies of the impacts of the TN visa expansion have been performed.

In the analysis below, two types of visa relaxations are considered: a one-time, five-percent increase that is implemented immediately, with economic effects working out in the impact year and then being sustained through 2030, and 20-percent increase phased in over five years. More broadly, I consider two types of innovation zones. One is North-South, including the US and Canada on the one hand and the Latin American and Caribbean countries and regions on the other. Second is a South-South arrangement, involving just the emerging and developing countries of Latin America and the Caribbean. Following this analysis I offer a rough guess about the potential impacts of extending free labor circulation worldwide in a "global innovation zone".

Model and Assumptions

I again put together a simple partial-equilibrium model of the MTW flows that would ensue from the visa policy changes and offer an assessment of the welfare benefits and costs. I assume that the policy interventions are permanent but consider just the impacts of visas issued from 2016 through 2030. In this context, note that a visa issued in 2030 would be valid for ten years so I consider the economic effects through 2040.

The model is presented in Appendix Two, along with parameter values and ranges. I assume, for lack of better evidence, that the visas are increased by five percent of each country's estimated initial MTW inward stock and that the demand for them arises across source countries (including Canada and the US) in proportion to their initial shares. In itself, this is not an overly strong assumption, for it is based on the idea that existing bilateral MTW migration reflects policy preferences and economic interests of migrants and sponsors across countries.

More strongly, I assume in the calculations that wage changes and tax collections in each source and destination country are based on this initial bilateral mobility. The obvious problem here is that the visas are issued for free circulation among zone members and it is impossible to predict how often skilled workers would change their temporary residences during the visa period and in which locations they would choose to work. It is possible, for example, that in comparison with the assumption here a larger proportion of MTW from developing countries would choose to work for a time in the US or Canada, where the wage gains would be highest, assuming they are sponsored for work there. After presenting the model's calculations I discuss below the qualitative biases this failure to capture free circulation is likely to have on the results. To preview that discussion, the added within-visa mobility would almost surely raise benefits more than it would raise costs, meaning

[17] http://cis.org/vaughan/700000-guestworker-visas-issued-2012.

the basic B/C ratios are likely biased downward. However, to the extent skilled laborers choose not to work in poor countries costs in the latter would go up.

Returning to the model, I assume that the visas are fully taken up, whether by individuals or employees of corporations or universities. Thus, in each country or region both inward and outward skilled-labor movements go up, with the aggregates simply being the sum of bilateral mobility. As indicated in Figure 1, these movements cause the wages of MTW non-movers to rise in the source countries and those in the destination countries to fall, depending on labor-demand elasticities. I adapt estimates from the literature suggesting that the elasticity is about .35 in origin countries and .25 in destination countries (Moses and Letnes 2004). It is possible that, because those estimates refer to all migration and the MTW market is presumably thinner and somewhat more specialized, the true elasticities are somewhat lower. However, in the current model changes in these parameters make virtually no difference in the implied welfare estimates, consistent with the literature (Clemens 2011). Thus, I keep them fixed in all simulations.

Following is the list of benefits and costs that I implement. The initial (and largest) benefit, as suggested in Figure 1, is the real income (productivity) gain to those who become mobile within the region. Since the visas would be issued by destination countries I calculate the wage gains to be the difference between destination and source wages, adjusted for the inherent productivity differential. This differential is a key parameter; again the question is whether a cross-border skilled worker is inherently less productive or suffers from characteristics in the source country that make all workers less productive. The empirical literature, based on numerical simulations, surveys, and macroeconomic accounting, generally finds that the majority of observed productivity differences are due to nation-specific total factor productivity, rather than characteristics of workers (Clemens et al 2008, Jasso and Rosenzweig 2009, Hall and Jones 1999). However, to be conservative in this regard I choose a low value (0.2) and a high value (0.5) for the productivity parameter. In essence, this means that a mover from, say, Brazil to Canada gains just 20% or 50% of the wage gap between those countries. Because there is only scarce information about averages wages for MTW in many developing countries, I assume they are 60% higher than GNI per capita (ATLAS) in 2010, the approximate figure for Canada and the US.

Regarding these international wage gaps, some difficult questions need to be addressed. First, it is unreasonable to imagine that skilled workers moving from a high-wage location, say Canada, to a low-wage location, say El Salvador, to work as engineers within a multinational enterprise would agree to be paid less than their existing Canadian salaries. Thus, I make the asymmetric assumption that such movements are not accompanied by any wage (productivity) loss.

Second, some may argue that the analysis in Figure 1 fails to account for the costs of living in different locations. In principle, these labor demand curves reflect real marginal productivities, which translate into real living standards in each country or region, so in theory this objection is unwarranted. Nonetheless, in practical terms there are many complexities about the true costs of housing and local services that might be treated in a fuller analysis. Yet it is not likely that such details would much alter the benefit-cost rankings available from the primary analysis. Moreover, we may interpret the productivity differential parameter as reflecting, in some degree, the higher costs of achieving a given basket of consumption services for in-movers. Thus, I follow the standard welfare-analytical literature here and use the productivity parameter to capture such differences.

Third, it is unreasonable to suppose that the wage gap between sources and destinations would remain the same over time, given that low-wage developing countries are likely to grow faster than high-wage developed countries over the next 15 years. Thus, I permit a two-percent wage catch-up between low-wage sources and high-wage destinations per year.

Fourth, an important parameter for understanding the distribution of the gains to mobility is the degree to which real wage increases are remitted as income payments back to the source countries. The most recent micro-data surveys suggest that about 70 percent of high-skilled migrants from developing countries send remittances home and that the average annual remittance is around $5,000 (Gibson and McKenzie 2010). Given the size of the South-North and South-South movements I simulate here, an average of $5,000 among 70 percent of workers would imply a remittance rate of 0.32.[18] Thus, I employ a low estimate of 0.2 and a high estimate of 0.32. Keep in mind that the size of remittances does not affect the overall within-zone welfare calculations, but does help determine the distribution of gains and losses between countries.

An element that does matter for welfare is the "fiscal externality" of labor mobility, which is at the heart of the brain drain (BD) controversy (Gibson and Mckenzie, 2011). Popular understanding of BD points to the loss of tax revenues in origin nations as highly skilled workers migrate abroad and to the loss of human capital. Here I comment on taxes and briefly defer the human-capital elements. The first question to address is whether skilled workers on temporary visas, who are not migrants seeking permanent residency or citizenship, pay income taxes to their home or host nations. There is not much evidence on which to base a decision here, so I take the US position of taxation at destination. That is, the United States taxes the incomes of even temporary in-migrants, such as those on H-1B visas. Assume also that, because remittances are taxed as gross income at the destination, the source countries choose not to engage in double taxation and therefore leave remittances untaxed. It is reasonable to suppose that taxing power remains with the host nations, given that these workers may be circulating among multiple countries during the visa periods. The decision adopted here will result in reduced tax revenues on those leaving but, because of the circulation of workers even low-income destination countries will collect income taxes. Indeed, the latter effect may dominate because inward skilled movers likely have higher salaries than the outward movers.

Next, tax-revenue changes *per se* are not welfare impacts. Rather, the welfare effects depend on how changes in taxes affect real productivity, whether through impacts on infrastructure or factor supplies. While there are numerous ways to approach this

[18] The initial database shows a marginally lower MTW wage in Canada than the United States but I ignore the possibility of North-North remittances.

question, the most neutral is to figure that where a country loses (gains) tax revenues on labor incomes it must increase (reduce) the revenues collected otherwise to replace them. These changes then reduce (raise) economic welfare via the marginal excess tax burden imposed on the economy, as noted in the model equations.

The second component of potential brain drain is the loss of human capital, which itself may have spillover productivity effects as first analyzed by Bhagwati and Hamada (1974). Specifically, a loss of human capital could reduce the productivity of remaining workers, if they are complementary in production. Similarly, emigration of health professionals could lower health status by reducing the supply of doctors and nurses. In analytical terms, the increase in source-country wages in Figure 1 reflects the greater scarcity of MTW workers who remain, assuming they are perfect substitutes for the out-movers. Instead, it may be that remaining workers are of lower quality or that there simply are not enough MTW to meet local needs. These impacts are often assumed to be pervasive in poor countries and support calls for limiting such mobility.

Several observations must be made here. First, extensive empirical analysis has failed to find evidence of significant human-capital externalities, whether in production, infrastructure, or public health (Clemens 2011). For example, African countries experiencing the largest outflows of medical professionals have systematically better health characteristics. For another, the large investments in education in the developing world in recent decades, if the externality story is correct, should have substantially increased productivity there but in many regions it has not, though this evidence is dated (Pritchett 2001). Further, there is virtually no evidence about whether such externalities, if they exist, are local, national, or international in scope. As Clemens (2011, p. 90) puts it, "Human capital externalities are…hard to locate and measure in the wild."

Next, although it is intuitive that net BD should be the outcome of skilled labor movements, more recent theory suggests that the opposite idea, of an endogenous "brain gain," is perhaps more likely. Specifically, the opportunity to move abroad for higher wages and better working conditions can induce more young people to invest in schooling, resulting in a higher home stock of educated labor (Mountford 1997). Empirical microeconomic evidence suggests that this impact is large enough to offset, with a lag, the direct impacts of out-movements on human capital (Batista et al 2012, Docquier and Rapoport 2012). I note further that the proposal considered in the present analysis relates to brain circulation rather than potential brain drain through permanent emigration.

Given these factors, I am skeptical about the conclusion of any brain drain or brain gain human capital externalities. Nonetheless, the issue continues to drive policy concerns about skilled-worker emigration, especially in the poorest economies.[19] Thus, in supplementary calculations of the North-South innovation zone I add a cost factor attempting to capture these potential externalities. I do this in a straightforward way by raising, for "Southern "countries" (i.e., not Canada or the US), the marginal excess burden of

[19] See UNCTAD (2012). This report is interesting for its advocacy of using some portion of remittance revenues in poor countries to invest in productive capacities, including in science and technology.

the tax loss on gross outward MTW movements by 50% (e.g., from 0.2 to 0.3) in order to capture the additional efficiency losses from brain drain.[20]

A potentially more relevant factor is the possibility of technological spillovers and dynamic effects, like those considered earlier in the case of R&D spending. Numerous channels have been identified in the economics literature for such effects. First, circulating business travelers have a positive and causal impact on patenting in the US by firms in destination countries (Hovhannisyan and Keller 2012). Second, foreign direct investment is, to a great extent, the process of transferring advanced technologies to advantageous production locations (Markusen 2002). One of the most critical components of this transfer is the ability of skilled managers and engineers to move among facilities for purposes of design and quality control. Third, there are significant productivity spillovers from inward FDI and technology licensing, emerging through multiple channels, including implementation of higher quality standards, demonstration effects and local business startups (Keller 2010).[21]

The question here is the extent to which temporary (if lengthy) circulation of MTW would support such technology spillovers, resulting in real GDP gains in destination countries. There are no direct estimates of how flows of skilled workers generate such impacts. Rather, the influences are indirectly measured through trade, FDI, and the like. In this context I make the following assumptions. First, suppose that each dollar of high-technology imports, FDI, and licensing is capable of raising local TFP by $0.03, a conservative estimate (Coe et al 1997, Keller 2004). Second, assume that increased flows of managerial and technical workers within the innovation zone facilitate additional inward technology transactions sufficient to capture half this impact, or $0.015. Because these externalities must be measured in dollar terms, I apply the associated parameters to the income gains earned (adjusted for productivity differentials) by movers at the destination, since these gains are the appropriate measure of increased human capital. Specifically, for movers from lower-wage to higher-wage locations the destination GDP gain is the relevant spillover parameter times the adjusted wage differential, multiplied by the number of movers. For movers from higher-wage to lower-wage locations the GDP impact is just the spillover rate times the source wage, multiplied by the number of movers. Put simply, for each $1 billion in wages earned by MTW visa recipients there is a spillover real GDP gain at the destination of $15 million.[22]

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[20] Readers are cautioned that this is only a rough guide to such a calculation. It likely is an overstatement since it does not account for brain gain from incoming MTW.

[21] It is worth noting that because these kinds of positive learning effects are stronger in countries with an established capacity to undertake R&D, there likely is an important complementarity between the R&D targets analyzed earlier and innovation zones. That is, a joint policy of increasing R&D and issuing more MTW circulation visas could have technology benefits greater than the sum of the individual projects. I am grateful to Kamal Saggi for this insight.

[22] More generally, such spillovers could occur anywhere within the zone, depending on where the movers work and transfer their knowledge gained. In particular, some of this knowledge would be transferred via enhanced technology flows to the movers' home nations, which is one motivation for suggesting an innovation zone as a pro-development policy. This issue does not matter for overall ratios of benefits to costs but is relevant for the distribution of gains and losses among members.

It is reasonable to assume that the effective spillover rates would vary depending on whether the mobility is North-North, North-South, South-North, or South-South. Thus, I scale the North-North parameter at 0.015 as the benchmark. Presumably, North-South flows embody greater differences in knowledge and I take a range for that parameter of 0.03 to 0.06. In contrast, I set the South-North spillover at half the benchmark, or 0.0075. Finally, there is certainly information content in South-South labor flows and I take a range there of 0.02 to 0.04. These spillovers are counted as real GDP gains in the welfare calculations.

It is possible to envision another source of GDP gains that would be spread across the innovation zone. As has often been noted in the literature, openness to trade seems to be pro-growth and trade liberalization generates dynamic gains significantly greater than static models would predict. For example, since 1950 countries that liberalized trade and investment regimes saw faster GDP growth than before liberalization, perhaps by 1.5 percentage points per year (Wacziarg and Welch 2008). Among the determinants of this extra growth are faster capital accumulation, greater access to technology, greater product variety and innovation of new goods (Broda and Weinstein 2006, Rutherford and Tarr 2002). In principle, greater openness to mobility of skilled labor should have a similar effect. One indication is that foreign-born technical workers are disproportionately involved in publication and innovation (as measured by patent ownership) in the United States (Kerr 2013, Stuen et al 2012, Hunt and Gauthier-Loiselle 2010). Moreover, return migration of inventive workers from the US to their home countries seems to expand productivity and patenting there (Kerr 2013).

Despite such findings, there is no clear evidence on which to base a computation of a growth dividend. The primary scenario here, a 5% growth in MTW visas, presumably is small in relation to the extensive trade liberalization of the last few decades. As such, one might anticipate a small boost to GDP, say less than 0.5 percentage points. As will be noted in the results below, the NPV's of program benefits calculated here without this growth dividend are on the order of $46 billion to $180 billion, depending on assumptions made. In that context, adding a growth dividend of just 0.4% of zone-participant country GDP's would dramatically expand the benefits and B/C ratios. Aggregate participant GDP of countries in the Western hemisphere is over $20 trillion, suggesting a growth boost over $80 billion. Such estimates could well dominate the basic program effects. Thus, I simply note the possibility that induced growth could be the largest overall gain without adding specific estimates.

Results

The initial scenario I consider is an innovation zone among the countries of the Western Hemisphere (excluding Cuba), permitting a five-percent increase in bilateral flows of MTW in proportion to their initial shares across countries and regions. For comparison purposes, this visa relaxation would translate into about 136,000 workers circulating in the region, with the largest share going to the US, at 97,000 workers. This may be compared to the current cap in the US of 65,000 H-1B visas, so it is a significant rise. This increase is assumed to be implemented in 2015 and have full effects, beginning in 2016 and lasting through 2040. Note that the idea is for these flows to continue through time, whether through extended visas or new workers as older visas expire, so the program benefits and costs could be expected to continue well beyond that time frame.

The results for a conservative set of parameter estimates, with a low ability to capture productivity differences, low remittance rate, and low technology spillover rates, are given in Table 6a. Participating countries and members are arrayed on the left-hand side and various welfare impacts by country are in the columns. Note first that there are large gains in income to the MTW movers, around $16.3 billion when discounted at 3%. About $3.2 billion would be remitted back to source countries. The implied efficiency gains (triangles in Figure 1) are small in both source and destination locations and they have no effective impact on the welfare calculations. Source countries lose about $2.2 billion in welfare due to lower tax collections on outflows, but destinations, including the developing economies, gain in the aggregate around $2.8 billion. Most of the developing countries in fact suffer net losses from these fiscal externalities. The technology spillovers in destinations are small, estimated at $1.2 billion over 25 years. This reflects both the limited amount of mobility modeled and, especially, the relatively low spillover parameters.

It is clear that total program benefits far exceed costs for all countries with the exception of Canada. Among developing nations the ratios range from 5.8 in Chile to over 47 in Central America. For the developing countries the presentation of large net gains is misleading, for the great bulk comes from income gains to workers who leave. As discussed earlier, these should be considered gains to the workers, not the source countries, though in this case the latter do benefit from remittances. These are included in the "net impact source" column, where the gains for developing countries are up to $1.1 billion in Mexico. The impact in Chile is small because only 6,000 workers leave that country and, because its MTW wage is already high, the income gains do not support significant remittances. However, these countries are both sources and destinations and the latter impacts add to the small welfare gains.

The final column lists benefit-cost ratios when the gains to movers (and therefore remittances as well) are excluded in order to focus on the fiscal and technological externalities. Here the absence of remittance income means that the B/C ratios are below unity for many developing countries, though Mexico and Argentina sustain significant net benefits. As for the overall program ratios, the appropriate figure is 9.3, placing skilled labor visas within an innovation zone nearly in the "phenomenal" range. Again, however, this large net benefit is largely due to moving workers enjoying higher real wages abroad and taking them out achieves a program ratio of 1.8, which is still noteworthy.

Table 6b shows the results from using medium parameters, which means the high-end technology spillovers combined with the low-end productivity gains and remittances. This change pushes more developing countries into a net-benefit situation and raises the overall B/C ratios a bit. This outcome points up the importance of actually achieving meaningful information external gains through brain circulation. Finally, Table 6c adds the high productivity and remittances parameters, which greatly increases the full-program B/C ratio as it considerably expands the income gains of movers, to over $40 billion. These changes also raise the B/C ratios in Canada and the US, because of the higher fiscal payoffs, accounting for the rise in the "mover exclusive" B/C ratio.

Table 6d offers a simple attempt to capture some potential negative human-capital externalities from brain drain, as noted above. Since it uses the high-value parameters it may be compared with Table 6c directly. The difference is that the marginal excess burden of the implicit tax increases in Southern countries to compensate for lower-productivity MTW remaining behind, which is 0.3 instead of 0.2. As may be seen this simple change raises the welfare losses from reduced tax collections in the developing countries and reduces their B/C ratios marginally. The overall program retains a B/C ratio of 18.3 with a discount rate of 3%.

A second scenario that can be treated briefly is offered in Table 7, which lists computations from a South-South innovation zone, using the high parameters, including for spillovers among these countries. For this purpose Canada and the US were eliminated from the tables and a five-percent visa relaxation was considered solely among the remaining hemispheric economies. As may be expected, the scale of the economic effects is far smaller in this case and, in particular, the income gains available to movers are much less. Moreover, many countries have a relatively large tax loss because they now tax in-movers at lower salaries than those earned by Northern workers. Thus, the overall B/C ratio falls from over 21 in Table 6c to 2.9, still quite noteworthy. The "without mover" ratio is just 1.5, still solidly greater than one but indicative of the more-limited technology flows and spillovers available in this arrangement. These results point to the importance of including both developed and developing countries in any prospective innovation zones to maximize such gains.

To summarize, even a modest increase in MTW visas within a Western Hemisphere innovation zone, especially one including Canada and the United States, would generate large net benefits for its participants. Most of these gains would go to the workers themselves, however, and how they would be split among countries and regions would depend on remittances and tax policy. The implied gains in local TFP from technological spillovers are small in relation to the full program effects and, from a political-economy standpoint, may not warrant the political costs of such a change. They are real, however, and offer a clear net benefit in knowledge-acquisition terms to participant countries. Moreover, if these impacts were to induce further within-zone innovation increases, a possibility not considered here, the net gains would be correspondingly larger.

A final scenario, much larger in scale than those above, is to permit 20% increases in these visas, phased in linearly over five years and again allocated among source countries according to initial MTW inward migrant stocks. I consider this situation in the North-South context, including Canada and the United States. I keep other parameters the same in implementing this case, which clearly involves far larger increases in within-hemisphere circulation of managerial and technical workers. With every annual increase in mobility the impacts on source and destination labor markers are calculated and the database is updated for the following year. Again, the visa increases exist from 2016 through 2020 and remain constant beyond that point permanently, though I compute impacts only through 2040.

Results are offered in Table 8, which relies on the high-value parameters. Not shown are the total increases in within-zone mobility, which amount to over 500,000 MTW visas across the hemisphere, ranging from about 4,800 going to Central America and nearly 390,000 to the United States. Whatever the political feasibility of such a policy, it would generate very large income growth for circulating professionals, who would gain a NPV of over $158 billion in income over the 25-year period, discounted at 3%. This increase would result in over $63 billion in additional remittances under the assumptions here. Again, efficiency costs in sources and efficiency gains in destinations are small in relation to total program effects. Welfare impacts associated with tax changes (fiscal externalities) are considerably larger, with a loss in sources of $8.7 billion, which is more than offset by gains in destination countries of over $14.6 billion.

The potential gains in GDP from spillovers into local TFP growth also would be considerably larger in this case. Discounted at 3%, such effects would amount to $6.9 billion in additional real GDP, compared to $1.9 billion in Table 6c. Note that about three-fourths of this increase would go to Mexico, Canada, and the US, where the cross-border circulation and associated learning and network economies would be greatest. Nonetheless, there would be notable gains in the Caribbean, South America, and Argentina as well.

In terms of benefits and costs, the larger visa program expands both, nearly in proportion to each other. Thus, the overall B/C ratios are similar to those in the one-time visa expansion above. Thus, the overall program ratio is around 21, with very large net gains in the developing countries. To be sure, the bulk of these net benefits come from wage increases earned by circulating workers who get to practice their professions in higher-wage areas. However, there are additional net gains arising from expanded tax revenues and spillover productivity gains from greater circulation of skilled workers.

Further Remarks

The calculations made here are rough and should be treated with caution, though I believe they are a reasonable guide to the kinds of essentially static outcomes one could anticipate with expanded MTW visa circulation programs. It is difficult to know whether these computed effects are underestimates or overestimates of what might ensue from the establishment of such innovation zones. In my view, the net gains are likely understated for at least two reasons. First, the economics literature does point to a complementarity between the mobility of skilled workers and the volumes of technology flows through trade, FDI and licensing. In that sense, an endogenous positive response of technology flows to expanded visas would markedly increase the spillover benefits noted above over time. Second, as discussed earlier, there may well be a growth dividend associated with greater MTW mobility, in line with what has been experienced from openness to trade and FDI. The back-of-the-envelope calculations above suggest this possibility could perhaps double the benefits of a mobility program.

We might also speculate on what effects could emerge from a global innovation zone, which would be an agreement among all WTO members to increase their visa allocations and permit free circulation within those visa periods. Building a database for analyzing this idea would be challenging given the limited information available about bilateral mobility patterns. As a simple benchmark, however, consider that the Western Hemisphere constitutes about 1/3 of world GDP, though it has a somewhat smaller portion of global managerial and technical workers. In that context, it would not be out of line to anticipate a scale of benefits and costs that would more than double their levels here, though the B/C ratios would likely be little affected.

Concluding Remarks

This paper has considered two potential ideas for expanding the access of developing countries to advanced global technologies and technical information. The first was for developing and emerging countries to implement policies (an R&D tax credit and direct government R&D expenditure) that would raise the share of R&D in GDP to targeted levels by 2030. Under the assumptions of the model there would be notable benefits available in terms of knowledge and learning externalities. However, these gains would be largely offset by increases in costs of financing the expansion (or diversion) of resources into R&D. The B/C ratio rarely exceeds about 1.4 in the most optimistic scenarios, ranking this suggestion rather low in comparison with other potential Sustainable Development Goals. Thus, emerging and developing countries likely would be better advised to focus on other forms of gaining better access.

The second idea presents a more attractive alternative, which is to form innovation zones among participant countries, within which technical and professional workers could circulate and work freely for up to 10 years. Even a modest (5%), one-time expansion of visas within a North-South Western Hemisphere innovation zone would offer a large B/C ratio, of around 21 to 1. An aggressive (20%) visa expansion over five years would establish a far larger scale of benefits and costs, but retain the same B/C ratio. Most of these gains come from higher salaries earned by workers, who may be expected to send more remittances home. The spillover TFP gains that could emerge from brain circulation are smaller but still quite significant. Excluding the direct income gains to movers these visa increases still may be expected to generate benefit-cost ratios of about 3 in the aggregate, with large net benefits to the more open developing countries, such as the Caribbean, Mexico and Argentina.

Some might argue that the relatively small presence of TFP spillovers available through this approach makes innovation zones an indirect and perhaps inefficient means of gaining more technology. In response, I would argue, first, that the absolute increases are notable. Second, the productivity gains are in the form of permanent increases in learning and network connections, meaning they would continue and accumulate beyond 2040 in ways that are not modeled here. Third, in order to be conservative I have not considered the obvious potential for further innovation to be induced by these spillovers. Thus, the analysis here is likely conservative in its calculation of technical gains available from innovation zones.

The primary response, however, is that additional openness to the mobility of skilled labor is, in fact, a direct means of expanded access to technology. So is liberalization of trade and investment barriers, but these policies have been pursued for some time and seem to be facing diminishing returns. The fact that movers would earn higher incomes, and make greater remittances, is a beneficial consequence that substantially increases the attractiveness of innovation zones.

There remains much we do not know about how circulatory patterns and endogenous responses in terms of growth in FDI, transfer of R&D facilities, and establishment of research networks would emerge within innovation zones. Given the significant responsiveness of technology flows to expanded movements of managerial and engineering labor that has been found in the literature, I suspect these endogenous effects could be large. Certainly, they are worth further study.

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List of Tables and Figures

Table 1: Basic figures on R&D ratios

	RD/GDP ratio current %	RD/GDP ratio current min	RD/GDP ratio current max	Annual ratio growth rate %	2030 expected RD ratio %	2030 target RD ratio	Target ratio growth rate %
DCs (26)	0.19	0.02	0.40	3.7	0.30	0.75	19.7
DCs (26)	0.19	0.02	0.40	3.7	0.30	0.5	11.0
ECs no China (35)	0.83	0.41	1.15	2.8	1.18	2.0	9.4
ECs no China (35)	0.83	0.41	1.15	2.8	1.18	1.5	5.4
China	1.69	1.69	1.69	9.5	4.10	3.0	5.2
MDCs (28)	2.61	1.25	4.54	1.3	3.12	3.5	1.0

Source: author's calculations using data from World Development Indicators. RD/GDP ratio is the within-group GNI-weighted average over 2008-10 or most recent (using 2012 GNI at ATLAS method); annual growth rate refers to percentage growth of weighted RD/GDP ratio from 2000-10 or closest years available. Sample sizes in parentheses depend on available R&D data.

Table 2. Country Samples for R&D Calculations

Country type	List
Developing	Albania, Armenia, Azerbaijan, Bolivia, Bosnia-Herzegovina, Colombia, Ecuador, Egypt, El Salvador, Ghana
	Guatemala, Indonesia, Iraq, Kazakhstan, Lesotho, Macedonia, Mongolia, Nigeria, Pakistan, Panama
	Paraguay, Philippines, Senegal, Sri Lanka, Thailand, Zambia
Emerging	Argentina, Belarus, Botswana, Brazil, Bulgaria, Chile, China, Costa Rica, Croatia, Cuba, Cyprus, Gabon, Greece
	Hong Kong, Hungary, India, Iran, Jordan, Latvia, Lithuania, Malaysia, Malta, Mexico, Moldova, Montenegro
	Morocco, Poland, Romania, Russian Federation, Serbia, Slovakia, South Africa, Tunisia, Turkey, Ukraine, Uruguay
Developed	Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Estonia, Finland, France, Germany, Iceland
	Ireland, Israel, Italy, Japan, Republic of Korea, Luxembourg, Netherlands, New Zealand, Norway, Portugal
	Singapore, Slovenia, Spain, Sweden, Switzerland, United Kingdom, United States

Definitions: DCs (developing countries) are lower middle income (LMI) or upper middle income (UMI) economies with R&D/GDP ratio of less than 0.4%; ECs (emerging countries) are LMI or UMI economies with R&D/GDP ratios of at least 0.4% or high-income (HI) economies with R&D/GDP of less than 1.25%; MDCs (developed countries) are HI economies with an R&D/GDP ratio of at least 1.25%. Source: data taken from World Development Indicators.

Table 3a. Computations of discounted benefit-cost ratios for incremental R&D targets in developing countries: raise RD/GDP ratio to 0.5% by 2030 (benefits and costs in $b).

Parameter	1	2	3	4	5	6	7		8	9
e private	0.6	0.8	0.6	0.6	0.6	0.6	0.6		0.6	0.6
e public	0.8	0.8	0.8	0.8	0.8	0.8	0.8		0.8	0.8
s weighted	0.6	0.7	0.6	0.6	0.6	0.6	0.6		0.6	0.6
Burden	0.2	0.2	0.3	0.2	0.2	0.2	0.2		0.2	0.2
Fixed	0.01	0.01	0.01	0.005	0.01	0.005	0.005		0.005	0.005
Innovation	0.01	0.01	0.01	0.01	0.04	0.04	0.04		0.18	0.30
Tax rate	0.25	0.25	0.25	0.25	0.25	0.25	0.2		0.25	0.25
Disc at 3%	NPV	NPV	NPV	NPV	NPV	NPV	NPV		NPV	NPV
Ben 15	18.7	23.4	18.7	18.7	20.8	20.8	20.8	Ben 40	45.9	64.4
Cost 15	17.2	20.9	21.4	16.9	17.1	16.8	16.8	Cost 40	16.8	16.8
B/C 15	1.09	1.12	0.88	1.11	1.22	1.24	1.24	B/C 40	2.73	3.86
Ben 25	19.5	24.1	19.5	19.5	23.8	23.8	23.8			
Cost 25	17.2	20.9	21.4	16.9	17.1	16.8	16.8			
B/C 25	1.13	1.12	0.91	1.15	1.39	1.42	1.41			
Disc at 5%	NPV	NPV	NPV	NPV	NPV	NPV	NPV		NPV	NPV
Ben 15	15.4	19.2	15.4	15.4	17.1	17.1	17.1	Ben 40	31.9	43.3
Cost 15	14.1	17.1	17.5	13.9	14.1	13.8	13.8	Cost 40	13.8	13.8
B/C 15	1.09	1.12	0.88	1.11	1.22	1.24	1.24	B/C 40	2.32	3.16
Ben 25	15.9	19.7	15.9	15.9	19.1	19.1	19.1			
Cost 25	14.1	17.1	17.5	13.9	14.1	13.8	13.8			
B/C 25	1.12	1.15	0.91	1.15	1.36	1.39	1.38			

Source: author's calculations, which assume a 5% annual real GDP growth rate. R&D target is assumed to be achieved by a tax credit to private investors for 50% of increment and direct government expenditure for remaining 50%.

Table 3b. Computations of discounted benefit-cost ratios for incremental R&D target in developing countries: raise RD/GDP ratio to 0.75% by 2030 (benefits and costs in $b).

Parameter	1	2	3	4	5	6	7		8	9
e private	0.6	0.8	0.6	0.6	0.6	0.6	0.6		0.6	0.6
e public	0.8	0.8	0.8	0.8	0.8	0.8	0.8		0.8	0.8
s weighted	0.6	0.7	0.6	0.6	0.6	0.6	0.6		0.6	0.6
Burden	0.2	0.2	0.3	0.2	0.2	0.2	0.2		0.2	0.2
Fixed	0.01	0.01	0.01	0.005	0.01	0.005	0.005		0.005	0.005
Innovation	0.01	0.01	0.01	0.01	0.04	0.04	0.04		0.18	0.30
Tax rate	0.25	0.25	0.25	0.25	0.25	0.25	0.2		0.25	0.25
Disc at 3%	NPV	NPV	NPV	NPV	NPV	NPV	NPV		NPV	NPV
Ben 15	41.1	51.2	41.1	41.1	45.6	45.6	45.6	Ben 40	100.5	141.2
Cost 15	37.0	44.6	45.7	36.2	37.0	36.2	36.5	Cost 40	36.2	36.2
B/C 15	1.11	1.15	0.90	1.13	1.23	1.26	1.25	B/C 40	2.78	3.89
Ben 25	42.7	52.9	42.7	42.6	52.2	52.2	52.2			
Cost 25	37.0	44.6	45.7	36.2	37.0	36.2	36.5			
B/C 25	1.15	1.19	0.94	1.18	1.41	1.44	1.43			
Disc at 5%									NPV	NPV
Ben 15	33.7	42.1	33.7	33.7	37.5	37.5	37.5	Ben 40	70.0	95.0
Cost 15	30.4	36.6	37.5	29.8	30.4	29.8	29.9	Cost 40	29.8	29.8
B/C 15	1.11	1.15	0.90	1.13	1.23	1.26	1.25	B/C 40	2.35	3.19
Ben 25	34.8	43.2	34.8	34.8	41.9	41.9	41.9			
Cost 25	30.4	36.6	37.5	29.8	30.4	29.8	29.9			
B/C 25	1.15	1.18	0.93	1.17	1.38	1.41	1.40			

Source: author's calculations, which assume a 5% annual real GDP growth rate. R&D target is assumed to be achieved by a tax credit to private investors for 50% of increment and direct government expenditure for remaining 50%.

Table 4a. Computations of discounted benefit-cost ratios for incremental R&D targets in emerging countries: raise RD/GDP ratio to 1.5% by 2030 (benefits and costs in $b).

Parameter	1	2	3	4	5	6	7		8	9
e private	0.6	0.8	0.6	0.6	0.6	0.6	0.6		0.6	0.6
e public	0.8	0.8	0.8	0.8	0.8	0.8	0.8		0.8	0.8
s weighted	0.6	0.7	0.6	0.6	0.6	0.6	0.6		0.6	0.6
Burden	0.2	0.2	0.3	0.2	0.2	0.2	0.2		0.2	0.2
Fixed	0.01	0.01	0.01	0.005	0.01	0.005	0.005		0.005	0.005
Innovation	0.01	0.01	0.01	0.01	0.04	0.04	0.04		0.18	0.30
Tax rate	0.25	0.25	0.25	0.25	0.25	0.25	0.2		0.25	0.25
Disc at 3%	NPV	NPV	NPV	NPV	NPV	NPV	NPV		NPV	NPV
Ben 15	143.7	179.2	143.7	143.7	159.6	159.6	159.6	Ben 40	347.2	486.5
Cost 15	132.2	159.9	163.8	129.5	131.4	128.7	129.1	Cost 40	128.6	127.8
B/C 15	1.09	1.12	0.88	1.11	1.22	1.24	1.24	B/C 40	2.70	3.81
Ben 25	149.2	184.8	149.2	149.2	181.9	181.9	181.9			
Cost 25	132.2	159.9	163.8	129.5	131.4	128.7	129.1			
B/C 25	1.13	1.16	0.91	1.15	1.38	1.41	1.41			
Disc at 5%	NPV	NPV	NPV	NPV	NPV	NPV	NPV		NPV	NPV
Ben 15	118.2	147.4	118.2	118.2	131.3	131.3	131.3	Ben 40	242.7	328.6
Cost 15	108.7	131.5	134.7	106.5	108.0	105.8	106.1	Cost 40	105.8	105.2
B/C 15	1.09	1.12	0.88	1.11	1.22	1.24	1.24	B/C 40	2.29	3.12
Ben 25	121.9	151.2	121.9	121.9	146.4	146.4	146.4			
Cost 25	108.7	131.5	134.7	106.5	108.0	105.8	106.1			
B/C 25	1.12	1.15	0.91	1.14	1.35	1.38	1.38			

Source: author's calculations, which assume a 3.5% annual real GDP growth rate. R&D target is assumed to be achieved by a tax credit to private investors for 50% of increment and direct government expenditure for remaining 50%.

Table 4b. Computations of discounted benefit-cost ratios for incremental R&D targets in emerging countries: raise RD/GDP ratio to 2.0% by 2030 (benefits and costs in $b).

Parameter	1	2	3	4	5	6	7		8	9
e private	0.6	0.8	0.6	0.6	0.6	0.6	0.6		0.6	0.6
e public	0.8	0.8	0.8	0.8	0.8	0.8	0.8		0.8	0.8
s weighted	0.6	0.7	0.6	0.6	0.6	0.6	0.6		0.6	0.6
Burden	0.2	0.2	0.3	0.2	0.2	0.2	0.2		0.2	0.2
Fixed	0.01	0.01	0.01	0.005	0.01	0.005	0.005		0.005	0.005
Innovation	0.01	0.01	0.01	0.01	0.04	0.04	0.04		0.18	0.30
Tax rate	0.25	0.25	0.25	0.25	0.25	0.25	0.2		0.25	0.25
Disc at 3%									NPV	NPV
Ben 15	364.7	455.0	364.7	364.7	405.2	405.2	405.2	Ben 40	881.5	1235.0
Cost 15	335.5	406.0	415.8	328.7	333.4	326.7	327.6	Cost 40	326.4	324.4
B/C 15	1.09	1.12	0.88	1.11	1.22	1.24	1.24	B/C 40	2.70	3.81
Ben 25	378.8	469.1	378.8	378.8	461.6	461.6	461.6			
Cost 25	335.5	406.0	415.8	328.7	333.4	326.7	327.6			
B/C 25	1.13	1.16	0.91	1.15	1.38	1.41	1.41			
Disc at 5%									NPV	NPV
Ben 15	300.0	374.2	300.0	300.0	333.3	333.3	333.3	Ben 40	616.1	834.2
Cost 15	275.9	333.9	341.6	270.4	274.2	268.7	269.5	Cost 40	268.6	267.0
B/C 15	1.09	1.12	0.88	1.11	1.22	1.24	1.24	B/C 40	2.29	3.12
Ben 25	309.5	383.8	309.5	309.5	371.5	371.5	371.5			
Cost 25	275.9	333.9	342.0	270.4	274.2	268.7	269.5			
B/C 25	1.12	1.15	0.91	1.14	1.35	1.38	1.38			

Source: author's calculations, which assume a 3.5% annual real GDP growth rate. R&D target is assumed to be achieved by a tax credit to private investors for 50% of increment and direct government expenditure for remaining 50%.

Figure 1. Basic welfare impacts of skilled labor movements

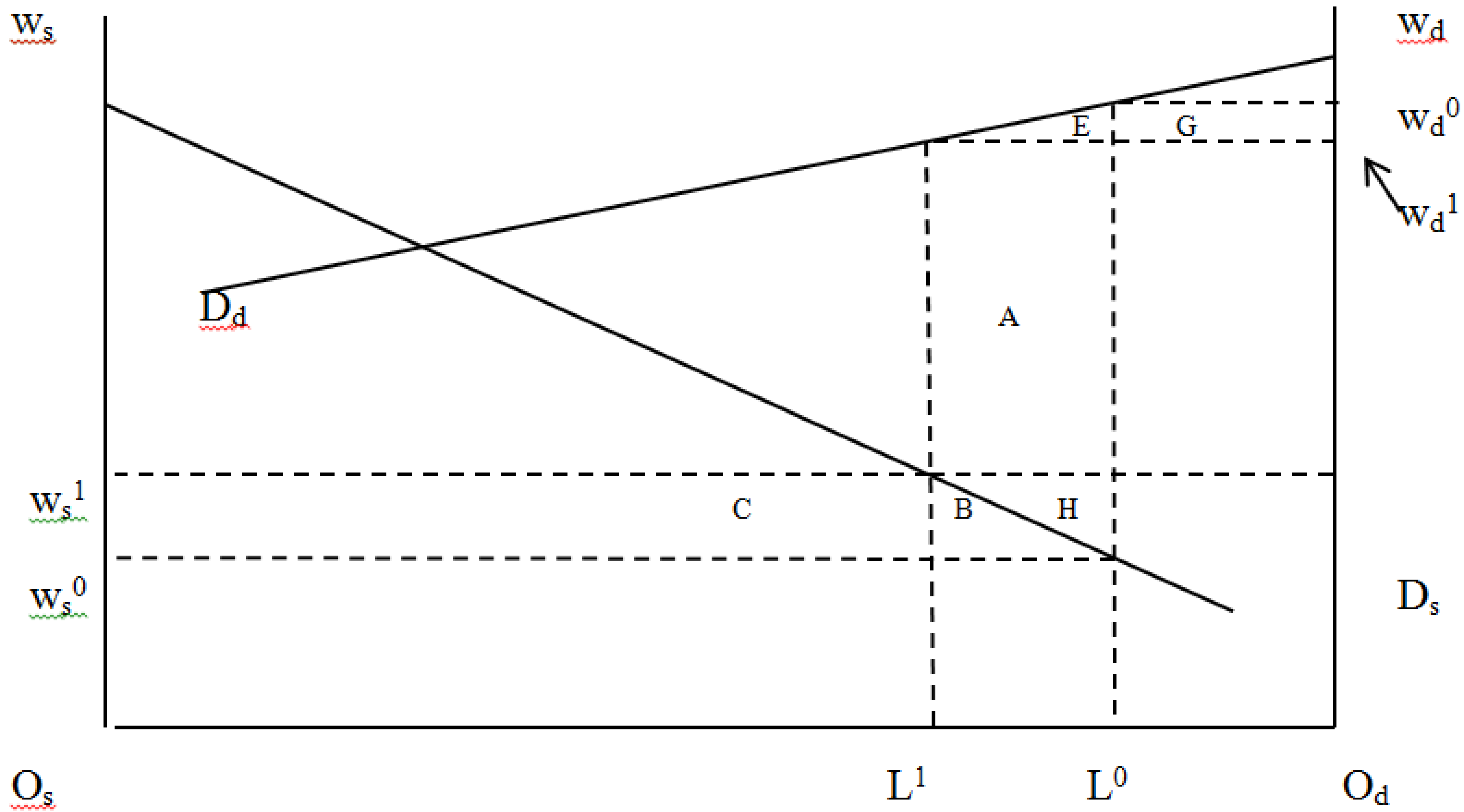

Table 5a. Estimates of Intra-Americas Bilateral Migrant Stocks of Managerial and Technical Workers, 2000

	Destination									
Origin	CAR	MEX	CAM	ARG	BRA	CHL	SAM	CAN	USA	TOTAL
CAR	11,069	645	907	82	8	31	1,954	46,538	381,283	442,517
MEX	517	-	3,066	720	270	421	2,244	8,384	570,959	586,580
CAM	226	1,791	7,876	16	26	24	122	8,028	110,386	128,494
ARG	611	1,622	322	-	7,189	11,922	17,936	3,580	30,982	74,164
BRA	248	521	199	7,749	-	1,620	15,907	3,869	49,827	79,941
CHL	559	1,262	487	70,074	5,843	-	6,050	8,330	25,022	117,627
SAM	2,321	2,598	376	62,059	7,111	5,741	26,914	18,263	149,902	275,283
CAN	1,813	1,813	433	299	339	488	947	-	325,912	332,045
USA	32,148	81,500	3,826	1,872	2,795	1,576	5,025	112,960	-	241,703
TOTAL	49,512	91,752	17,493	142,872	23,581	21,823	77,099	209,952	1,644,272	2,278,356

Notes: CAR = Caribbean, MEX = Mexico, CAM = Central America, excluding Mexico, ARG = Argentina, BRA = Brazil, CHL = Chile, SAM = other South America, CAN = Canada, USA = United States. Source: computed by author from sources detailed in text.

Table 5b. Estimates of Intra-Americas Bilateral Migrant Stocks of Managerial and Technical Workers, 2010

	Destination								
Origin	CAR	MEX	CAM	ARG	BRA	CHL	SAM	CAN	USA	TOTAL
CAR	12,870	450	1,255	77	12	57	2,486	56,361	369,138	442,707
MEX	629	-	3,737	678	229	760	3,155	13,582	704,815	727,586
CAM	277	2,015	11,563	15	26	43	158	10,218	142,167	166,483
ARG	720	2,476	454	-	6,938	21,540	20,956	5,804	48,253	107,140
BRA	330	740	268	7,292	-	2,927	16,294	5,782	81,989	115,622
CHL	652	1,243	681	65,937	6,089	-	8,292	10,166	30,130	123,189
SAM	2,813	3,785	533	58,395	6,323	10,373	38,870	26,576	188,247	335,917
CAN	2,433	1,816	552	282	302	881	1,350	-	382,787	390,403
USA	30,211	125,147	4,889	1,762	2,551	2,848	7,199	136,944	-	311,550
TOTAL	50,935	137,673	23,933	134,437	22,471	39,429	98,761	265,433	1,947,527	2,720,599

Notes: CAR = Caribbean, MEX = Mexico, CAM = Central America, excluding Mexico, ARG = Argentina, BRA = Brazil, CHL = Chile, SAM = other South America, CAN = Canada, USA = United States. Source: computed by author from sources detailed in text.

Table 6a. Computations of discounted benefit-cost ratios for North-South Western Hemisphere Innovation Zone: 5% increase in visas for managerial and technical workers, 10-year duration (low parameter values)

Parameter values: δ = 0.2, ρ = 0.2, i_{ns} = .03, i_{ss} = .02														Without
		Inc gains	Remit to	Eff cost	Tax loss	Net impact	Eff gain	Tax gain	Spill gain	Net impact	Total	Total		movers
		out-movers	source	source	source	source	destination	destination	destination	destination	benefits	costs	B/C ratio	B/C ratio
Benefits and costs ($m)		A	B	C	D	B+C+D	E	F	G	E+F+G	A+E+F+G	D		
disc 3%	CAR	4024.0	804.8	-14.8	-161.4	628.6	0.1	70.6	72.4	143.2	4167.2	-161.4	25.8	0.9
	MEX	6780.3	1356.1	-10.6	-272.5	1073.0	0.3	271.1	268.5	539.9	7320.2	-272.5	26.9	2.0
	CAM	1581.0	316.2	-0.4	-33.7	282.1	0.0	14.1	14.7	28.8	1609.8	-33.7	47.7	0.9
	ARG	591.8	118.4	-0.3	-27.7	90.4	0.3	62.3	43.0	105.6	697.4	-27.7	25.2	3.8
	BRA	812.1	162.4	-0.1	-47.4	114.9	0.0	13.6	8.9	22.4	834.5	-47.4	17.6	0.5
	CHL	343.8	68.8	-1.4	-65.1	2.3	0.1	20.1	10.3	30.5	374.3	-65.1	5.8	0.5
	SAM	2073.6	414.7	-1.2	-114.6	298.9	0.1	36.9	36.5	73.5	2147.0	-114.6	18.7	0.6
	CAN	114.1	0.0	-12.1	-801.3	-813.4	4.0	378.2	157.5	539.6	653.7	-801.3	0.8	0.7
	USA	0.0	0.0	-0.9	-656.6	-657.5	26.4	1892.1	557.6	2476.1	2476.1	-656.6	3.8	3.8
	TOTAL	16320.7	3241.3	-41.9	-2180.2	1019.2	31.4	2758.8	1169.4	3959.6	20280.3	-2180.2	9.3	1.8
														Without
		Inc gains	Remit to	Eff cost	Tax loss	Net impact	Eff gain	Tax gain	Spill gain	Net impact	Total	Total		movers
		out-movers	source	source	source	source	dest	dest	dest	destination	benefits	costs	B/C ratio	B/C ratio
Benefits and costs ($m)	CAR	3383.0	676.6	-12.2	-133.2	531.2	0.1	58.3	59.8	118.2	3501.1	-133.2	26.3	0.9
disc 5%	MEX	5700.2	1140.0	-8.8	-224.8	906.4	0.2	223.7	221.5	445.4	6145.7	-224.8	27.3	2.0
	CAM	1329.1	265.8	-0.3	-27.8	237.7	0.0	11.6	12.2	23.8	1352.9	-27.8	48.6	0.9
	ARG	497.5	99.5	-0.3	-22.8	76.4	0.3	51.4	35.5	87.1	584.7	-22.8	25.6	3.8
	BRA	682.7	136.5	-0.1	-39.1	97.4	0.0	11.2	7.3	18.5	701.2	-39.1	17.9	0.5
	CHL	289.0	57.8	-1.2	-53.7	2.9	0.1	16.6	8.5	25.2	314.2	-53.7	5.9	0.5
	SAM	1743.2	348.6	-1.0	-94.6	253.1	0.1	30.4	30.1	60.6	1803.9	-94.6	19.1	0.6
	CAN	95.9	0.0	-10.0	-661.1	-671.1	3.3	312.0	129.9	445.2	541.2	-661.1	0.8	0.7
	USA	0.0	0.0	-0.8	-541.8	-542.5	21.8	1561.1	460.1	2043.0	2043.0	-541.8	3.8	3.8
	TOTAL	13720.8	2725.0	-34.6	-1798.9	891.5	25.9	2276.3	964.9	3267.1	16987.8	-1798.9	9.4	1.8

Table 6b. Computations of discounted benefit-cost ratios for North-South Western Hemisphere Innovation Zone: 5% increase in visas for managerial and technical workers, 10-year duration (medium parameter values)

Parameter values: $\delta = 0.2$, $\rho = 0.2$, $i_{ns} = .06$, $i_{ss} = .04$														Without
		Inc gains	Remit to	Eff cost	Tax loss	Net impact	Eff gain	Tax gain	Spill gain	Net impact	Total	Total		movers
		out-movers	source	source	source	source	destination	destination	destination	destination	benefits	costs	B/C ratio	B/C ratio
Benefits and costs ($m)		A	B	C	D	B+C+D	E	F	G	E+F+G	A+E+F+G	D		
disc 3%	CAR	4024.0	804.8	-14.8	-161.4	628.6	0.1	70.6	144.9	215.6	4239.6	-161.4	26.3	1.3
	MEX	6780.3	1356.1	-10.6	-272.5	1073.0	0.3	271.1	537.0	808.4	7588.7	-272.5	27.9	3.0
	CAM	1581.0	316.2	-0.4	-33.7	282.1	0.0	14.1	29.5	43.6	1624.6	-33.7	48.2	1.3
	ARG	591.8	118.4	-0.3	-27.7	90.4	0.3	62.3	85.9	148.6	740.4	-27.7	26.8	5.4
	BRA	812.1	162.4	-0.1	-47.4	114.9	0.0	13.6	17.8	31.3	843.4	-47.4	17.8	0.7
	CHL	343.8	68.8	-1.4	-65.1	2.3	0.1	20.1	20.6	40.8	384.6	-65.1	5.9	0.6
	SAM	2073.6	414.7	-1.2	-114.6	298.9	0.1	36.9	73.0	110.0	2183.5	-114.6	19.1	1.0
	CAN	114.1	0.0	-12.1	-801.3	-813.4	4.0	378.2	157.5	539.6	653.7	-801.3	0.8	0.7
	USA	0.0	0.0	-0.9	-656.6	-657.5	26.4	1892.1	557.6	2476.1	2476.1	-656.6	3.8	3.8
	TOTAL	16320.7	3241.3	-41.9	-2180.2	1019.2	31.4	2758.8	1623.8	4414.0	20734.6	-2180.2	9.5	2.0
														Without
		Inc gains	Remit to	Eff cost	Tax loss	Net impact	Eff gain	Tax gain	Spill gain	Net impact	Total	Total		movers
		out-movers	source	source	source	source	dest	dest	dest	destination	benefits	costs	B/C ratio	B/C ratio
Benefits and costs ($m)	CAR	3383.0	676.6	-12.2	-133.2	531.2	0.1	58.3	119.5	177.9	3560.9	-133.2	26.7	1.3
disc 5%	MEX	5700.2	1140.0	-8.8	-224.8	906.4	0.2	223.7	443.1	667.0	6367.2	-224.8	28.3	3.0
	CAM	1329.1	265.8	-0.3	-27.8	237.7	0.0	11.6	24.3	35.9	1365.1	-27.8	49.0	1.3
	ARG	497.5	99.5	-0.3	-22.8	76.4	0.3	51.4	70.9	122.6	620.1	-22.8	27.2	5.4
	BRA	682.7	136.5	-0.1	-39.1	97.4	0.0	11.2	14.7	25.8	708.5	-39.1	18.1	0.7
	CHL	289.0	57.8	-1.2	-53.7	2.9	0.1	16.6	17.0	33.7	322.7	-53.7	6.0	0.6
	SAM	1743.2	348.6	-1.0	-94.6	253.1	0.1	30.4	60.2	90.7	1834.0	-94.6	19.4	1.0
	CAN	95.9	0.0	-10.0	-661.1	-671.1	3.3	312.0	129.9	445.2	541.2	-661.1	0.8	0.7
	USA	0.0	0.0	-0.8	-541.8	-542.5	21.8	1561.1	460.1	2043.0	2043.0	-541.8	3.8	3.8
	TOTAL	13720.8	2725.0	-34.6	-1798.9	891.5	25.9	2276.3	1339.8	3642.0	17362.7	-1798.9	9.7	2.0

Table 6c. Computations of discounted benefit-cost ratios for North-South Western Hemisphere Innovation Zone: 5% increase in visas for managerial and technical workers, 10-year duration (high parameter values)

Parameter values: $\delta = 0.5$, $\rho = 0.32$, $i_{ns} = .06$, $i_{ss} = .04$														Without
		Inc gains	Remit to	Eff cost	Tax loss	Net impact	Eff gain	Tax gain	Spill gain	Net impact	Total	Total		movers
		out-movers	source	source	source	source	destination	destination	destination	destination	benefits	costs	B/C ratio	B/C ratio
Benefits and costs ($m)		A	B	C	D	B+C+D	E	F	G	E+F+G	A+E+F+G	D		
disc 3%	CAR	10059.9	3219.2	-14.8	-161.4	3042.9	0.1	70.7	145.4	216.2	10276.2	-161.4	63.7	1.3
	MEX	16950.9	5424.3	-10.6	-272.5	5141.2	0.3	271.3	538.3	809.9	17760.7	-272.5	65.2	3.0
	CAM	3952.5	1264.8	-0.4	-33.7	1230.7	0.0	14.1	29.5	43.6	3996.1	-33.7	118.5	1.3
	ARG	1479.5	473.5	-0.3	-27.7	445.5	0.3	62.3	85.9	148.6	1628.1	-27.7	58.8	5.4
	BRA	2030.2	649.7	-0.1	-47.4	602.2	0.0	14.0	20.0	34.0	2064.2	-47.4	43.6	0.7
	CHL	859.5	275.0	-1.4	-65.1	208.5	0.1	22.5	28.2	50.8	910.3	-65.1	14.0	0.8
	SAM	5183.9	1658.9	-1.2	-114.6	1543.1	0.1	37.4	75.9	113.4	5297.3	-114.6	46.2	1.0
	CAN	285.2	0.0	-12.1	-801.3	-813.4	4.0	443.4	177.2	624.7	909.9	-801.3	1.1	0.8
	USA	0.0	0.0	-0.9	-656.6	-657.5	26.4	2721.4	804.9	3552.7	3552.7	-656.6	5.4	5.4
	TOTAL	40801.7	12965.3	-41.9	-2180.2	10743.1	31.4	3657.2	1905.3	5593.9	46395.5	-2180.2	21.3	2.6
														Without
		Inc gains	Remit to	Eff cost	Tax loss	Net impact	Eff gain	Tax gain	Spill gain	Net impact	Total	Total		movers
		out-movers	source	source	source	source	dest	dest	dest	destination	benefits	costs	B/C ratio	B/C ratio
Benefits and costs ($m)	CAR	8457.4	2706.4	-12.2	-133.2	2561.0	0.1	58.3	120.0	178.4	8635.8	-133.2	64.8	1.3
disc 5%	MEX	14250.6	4560.2	-8.8	-224.8	4326.6	0.2	223.9	444.1	668.2	14918.8	-224.8	66.4	3.0
	CAM	3322.9	1063.3	-0.3	-27.8	1035.2	0.0	11.6	24.3	35.9	3358.8	-27.8	120.7	1.3
	ARG	1243.9	398.0	-0.3	-22.8	375.0	0.3	51.4	70.9	122.6	1366.5	-22.8	59.8	5.4
	BRA	1706.8	546.2	-0.1	-39.1	507.0	0.0	11.6	16.5	28.0	1734.8	-39.1	44.4	0.7
	CHL	722.6	231.2	-1.2	-53.7	176.4	0.1	18.6	23.3	41.9	764.5	-53.7	14.2	0.8
	SAM	4358.1	1394.6	-1.0	-94.6	1299.1	0.1	30.9	62.6	93.5	4451.7	-94.6	47.1	1.0
	CAN	239.8	0.0	-10.0	-661.1	-671.1	3.3	365.9	146.2	515.4	755.2	-661.1	1.1	0.8
	USA	0.0	0.0	-0.8	-541.8	-542.5	21.8	2245.4	664.1	2931.3	2931.3	-541.8	5.4	5.4
	TOTAL	34301.9	10899.9	-34.6	-1798.9	9066.4	25.9	3017.5	1572.1	4615.5	38917.4	-1798.9	21.6	2.6

Table 6d. Computations of discounted benefit-cost ratios for North-South Western Hemisphere Innovation Zone: 5% increase in visas for managerial and technical workers, 10-year duration (high parameter values), with allowance for brain drain losses

Parameter values: $\delta = 0.5$, $\rho = 0.32$, $i_{ns} = .06$, $i_{ss} = .04$														Without
		Inc gains	Remit to	Eff cost	Tax loss	Net impact	Eff gain	Tax gain	Spill gain	Net impact	Total	Total		movers
		out-movers	source	source	source	source	destination	destination	destination	destination	benefits	costs	B/C ratio	B/C ratio
Benefits and costs ($m)		A	B	C	D	B+C+D	E	F	G	E+F+G	A+E+F+G	D		
disc 3%	CAR	10059.9	3219.2	-14.8	-242.1	2962.2	0.1	70.7	145.4	216.2	10276.2	-242.1	42.4	0.9
	MEX	16950.9	5424.3	-10.6	-408.7	5004.9	0.3	271.3	538.3	809.9	17760.7	-408.7	43.5	2.0
	CAM	3952.5	1264.8	-0.4	-50.6	1213.9	0.0	14.1	29.5	43.6	3996.1	-50.6	79.0	0.9
	ARG	1479.5	473.5	-0.3	-41.5	431.6	0.3	62.3	85.9	148.6	1628.1	-41.5	39.2	3.6
	BRA	2030.2	649.7	-0.1	-71.1	578.5	0.0	14.0	20.0	34.0	2064.2	-71.1	29.0	0.5
	CHL	859.5	275.0	-1.4	-97.6	176.0	0.1	22.5	28.2	50.8	910.3	-97.6	9.3	0.5
	SAM	5183.9	1658.9	-1.2	-171.9	1485.8	0.1	37.4	75.9	113.4	5297.3	-171.9	30.8	0.7
	CAN	285.2	0.0	-12.1	-801.3	-813.4	4.0	443.4	177.2	624.7	909.9	-801.3	1.1	0.8
	USA	0.0	0.0	-0.9	-656.6	-657.5	26.4	2721.4	804.9	3552.7	3552.7	-656.6	5.4	5.4
	TOTAL	40801.7	12965.3	-41.9	-2541.4	10382.0	31.4	3657.2	1905.3	5593.9	46395.5	-2541.4	18.3	2.2
														Without
		Inc gains	Remit to	Eff cost	Tax loss	Net impact	Eff gain	Tax gain	Spill gain	Net impact	Total	Total		movers
		out-movers	source	source	source	source	dest	dest	dest	destination	benefits	costs	B/C ratio	B/C ratio
Benefits and costs ($m)	CAR	8457.4	2706.4	-12.2	-133.2	2561.0	0.1	58.3	120.0	178.4	8635.8	-133.2	64.8	1.3
disc 5%	MEX	14250.6	4560.2	-8.8	-224.8	4326.6	0.2	223.9	444.1	668.2	14918.8	-224.8	66.4	3.0
	CAM	3322.9	1063.3	-0.3	-27.8	1035.2	0.0	11.6	24.3	35.9	3358.8	-27.8	120.7	1.3
	ARG	1243.9	398.0	-0.3	-22.8	375.0	0.3	51.4	70.9	122.6	1366.5	-22.8	59.8	5.4
	BRA	1706.8	546.2	-0.1	-39.1	507.0	0.0	11.6	16.5	28.0	1734.8	-39.1	44.4	0.7
	CHL	722.6	231.2	-1.2	-53.7	176.4	0.1	18.6	23.3	41.9	764.5	-53.7	14.2	0.8
	SAM	4358.1	1394.6	-1.0	-94.6	1299.1	0.1	30.9	62.6	93.5	4451.7	-94.6	47.1	1.0
	CAN	239.8	0.0	-10.0	-661.1	-671.1	3.3	365.9	146.2	515.4	755.2	-661.1	1.1	0.8
	USA	0.0	0.0	-0.8	-541.8	-542.5	21.8	2245.4	664.1	2931.3	2931.3	-541.8	5.4	5.4
	TOTAL	34301.9	10899.9	-34.6	-1798.9	9066.4	25.9	3017.5	1572.1	4615.5	38917.4	-1798.9	21.6	2.6

Table 7. Computations of discounted benefit-cost ratios for South-South Western Hemisphere Innovation Zone: 5% increase in visas for managerial and technical workers, 10-year duration (high parameter values)

Parameter values: δ = 0.5, ρ = 0.32, i_{ss} = .04														Without
		Inc gains	Remit to	Eff cost	Tax loss	Net impact	Eff gain	Tax gain	Spill gain	Net impact	Total	Total		movers
		out-movers	source	source	source	source	destination	destination	destination	destination	benefits	costs	B/C ratio	B/C ratio
Benefits and costs ($th)		A	B	C	D	B+C+D	E	F	G	E+F+G	A+E+F+G	D		
disc 3%	CAR	194.6	62.3	-22.4	-6274.3	-6234.4	18.1	1378.3	5491.7	6888.0	7082.6	-6274.3	1.1	1.1
	MEX	1706.9	546.2	-1.7	-3350.4	-2805.9	1.6	2636.3	2021.4	4659.3	6366.2	-3350.4	1.9	1.4
	CAM	5906.8	1890.2	-2.5	-5140.7	-3253.0	3.1	1800.2	4541.8	6345.2	12252.0	-5140.7	2.4	1.2
	ARG	122329.8	39145.5	-74.7	-19355.5	19715.4	331.7	39777.6	53035.7	93145.1	215474.9	-19355.5	11.1	4.8
	BRA	4740.3	1516.9	-5.0	-10155.6	-8643.7	1.8	5491.6	4787.7	10281.1	15021.4	-10155.6	1.5	1.0
	CHL	0.0	0.0	-649.4	-30225.3	-30874.7	86.0	10100.5	4850.2	15036.8	15036.8	-30225.3	0.5	0.5
	SAM	35029.8	11209.6	-154.4	-44154.3	-33099.2	61.2	13346.8	26623.3	40031.3	75061.2	-44154.3	1.7	0.9
	TOTAL	169908.2	54370.6	-910.1	-118656.1	-65195.6	503.6	74531.4	101351.8	176386.8	346295.1	-118656.1	2.9	1.5
														Without
		Inc gains	Remit to	Eff cost	Tax loss	Net impact	Eff gain	Tax gain	Spill gain	Net impact	Total	Total		movers
		out-movers	source	source	source	source	dest	dest	dest	destination	benefits	costs	B/C ratio	B/C ratio
Benefits and costs ($th)	CAR	163.6	52.3	-18.5	-5176.9	-5143.0	14.9	1221.7	4867.6	6104.1	6267.7	-5176.9	1.2	1.2
disc 5%	MEX	1435.0	459.2	-1.4	-2764.4	-2306.6	1.4	2336.7	1791.6	4129.7	5564.7	-2764.4	2.0	1.5
	CAM	4965.8	1589.1	-2.1	-4241.6	-2654.6	2.6	1595.6	4025.7	5623.9	10589.7	-4241.6	2.5	1.3
	ARG	102842.5	32909.6	-61.6	-15970.2	16877.8	273.7	35257.0	47008.3	82539.0	185381.5	-15970.2	11.6	5.2
	BRA	3985.2	1275.3	-4.2	-8379.4	-7108.3	1.5	4867.5	4243.5	9112.5	13097.7	-8379.4	1.6	1.1
	CHL	0.0	0.0	-535.8	-24939.0	-25474.8	71.0	8952.6	4299.0	13322.6	13322.6	-24939.0	0.5	0.5
	SAM	29449.6	9423.9	-127.4	-36431.8	-27135.4	50.5	11830.0	23597.6	35478.1	64927.6	-36431.8	1.8	1.0
	TOTAL	142841.8	45709.4	-750.9	-97903.3	-52944.9	415.5	66061.0	89833.3	156309.8	299151.6	-97903.3	3.1	1.6

Table 8. Computations of discounted benefit-cost ratios for North-South Western Hemisphere Innovation Zone: 20% increase in visas for managerial and technical workers phased in over 5 years, 10-year duration (high parameter values)

Parameter values: $\delta = 0.5$, $\rho = 0.32$, $i_{ns} = .06$, $i_{ss} = .04$														Without
		Inc gains	Remit to	Eff cost	Tax loss	Net impact	Eff gain	Tax gain	Spill gain	Net impact	Total	Total		movers
		out-movers	source	source	source	source	destination	destination	destination	destination	benefits	costs	B/C ratio	B/C ratio
Benefits and costs ($m)		A	B	C	D	B+C+D	E	F	G	E+F+G	A+E+F+G	D		
disc 3%	CAR	39078.3	15699.9	-225.6	-643.6	14830.7	2.1	281.8	579.4	863.3	39941.7	-643.6	62.1	1.3
	MEX	65846.5	26454.2	-162.1	-1086.4	25205.7	4.1	1081.8	2144.2	3230.2	69076.7	-1086.4	63.6	3.0
	CAM	15353.7	6168.4	-5.4	-134.5	6028.6	0.1	56.1	117.6	173.7	15527.4	-134.5	115.5	1.3
	ARG	5747.4	2309.0	-4.6	-110.3	2194.1	5.2	248.4	342.6	596.3	6343.7	-110.3	57.5	5.4
	BRA	7886.4	3168.4	-1.3	-188.9	2978.2	0.0	55.8	75.6	131.5	8017.9	-188.9	42.4	0.7
	CHL	3338.7	1341.4	-21.8	-259.4	1060.1	1.6	90.1	90.5	182.2	3520.9	-259.4	13.6	0.7
	SAM	20137.2	8090.2	-18.1	-456.9	7615.2	1.1	149.2	297.9	448.2	20585.4	-456.9	45.1	1.0
	CAN	1107.9	0.0	-184.9	-3194.7	-3379.6	61.0	1770.0	1626.6	3457.6	4565.6	-3194.7	1.4	1.1
	USA	0.0	0.0	-14.4	-2617.9	-2632.3	402.8	10854.6	1616.2	12873.7	12873.7	-2617.9	4.9	4.9
	TOTAL	158496.0	63231.5	-638.4	-8692.6	53900.5	478.2	14587.9	6890.7	21956.8	180452.8	-8692.6	20.8	2.5
Benefits and costs ($m)	CAR	34325.3	13578.8	-193.7	-556.7	12828.5	1.8	243.8	501.1	746.7	35072.0	-556.7	63.0	1.3
disc 5%	MEX	57837.7	22880.2	-139.2	-939.6	21801.4	3.6	935.7	1854.5	2793.8	60631.5	-939.6	64.5	3.0
	CAM	13486.3	5335.1	-4.6	-116.3	5214.1	0.1	48.5	101.7	150.3	13636.5	-116.3	117.2	1.3
	ARG	5048.3	1997.1	-4.0	-95.4	1897.7	4.5	214.9	296.4	515.7	5564.0	-95.4	58.3	5.4
	BRA	6927.2	2740.3	-1.1	-163.4	2575.8	0.0	48.3	65.4	113.8	7040.9	-163.4	43.1	0.7
	CHL	2932.6	1160.1	-18.8	-224.4	917.0	1.4	77.9	78.3	157.5	3090.2	-224.4	13.8	0.7
	SAM	17687.9	6997.2	-15.5	-395.2	6586.5	1.0	129.0	257.6	387.6	18075.6	-395.2	45.7	1.0
	CAN	973.2	0.0	-158.7	-2763.1	-2921.8	52.4	1530.8	1406.9	2990.1	3963.3	-2763.1	1.4	1.1
	USA	0.0	0.0	-12.4	-2264.2	-2276.6	345.8	9388.2	1397.9	11131.9	11131.9	-2264.2	4.9	4.9
	TOTAL	139218.5	54688.8	-548.1	-7518.2	46622.5	410.6	12617.0	5959.7	18987.3	158205.8	-7518.2	21.0	2.5

Appendix One: Equations for Partial Equilibrium Model of R&D Policies

This simple PE model is slightly adapted from that in Lester (2012), who performed a benefit-cost analysis of two Canadian policies: an R&D tax credit and a "contribution funding" program with extensive reporting requirements. As noted in the text, I assume that DCs and ECs, as groups, implement an R&D tax credit to encourage 50% of the required incremental gain in real R&D spending and offer direct grants as government expenditure for the other 50%.

Model equations:

Weighted subsidy rate: $s = 0.5*s_p + 0.5*s_g$

Spillover benefits private: $L = (I*e_p*\varepsilon(s-c))/(1+(s-c))*\varepsilon$

Spillover benefits public: $L = (I*e_g*\varepsilon(s-c))/(1+(s-c))*\varepsilon$

Induced innovation benefits: $D = i*I$ or $D = i'*I$

Efficiency loss: $P = (I/(1+(s-c)*\varepsilon))*[(s-c) + 0.5(s-c)^2*\varepsilon - (s+a)*(1+(s-c)*\varepsilon]$

Financing costs: $B = b*(s*I + A - t*(L + P))$

Fixed costs to firms: $F = f*I$

Administration costs: $A = g*I$

Welfare impact: $W = L + D + P – B – F – A$

Variable and parameter list:

	Variable or parameter	Range
I	Target real R&D by year	Varies by year
e_p	Spillover parameter from private R&D	0.6, 0.8
e_g	Spillover parameter from public R&D	0.8
ε	Absolute value of R&D price elasticity	1.0
s_p	Effective subsidy rate to private R&D	0.2, 0.4
s_g	Effective subsidy rate to public R&D	1.0
c	Marginal program compliance cost	0.008
a	Marginal program administrative cost	0.0015
i	Domestic innovation productivity gains	0.01, 0.04
i’	Global innovation usage gains	0.18, 0.30
b	Marginal excess tax burden	0.2, 0.3
t	Marginal effective tax rate on GDP	0.2, 0.25

f	Fixed cost parameter to firms	0.005, 0.01
g	Fixed cost parameter to government	0.005

Appendix Two: Equations for Partial Equilibrium Model of Innovation Zones

This basic model is designed to capture the effects of relaxations in skilled-labor visas on behalf of managerial and technically skilled workers, permitting free work circulation within the region for 10 years, which may be renewed though the visa levels remain higher permanently. The policy considered is for countries to raise their skilled-labor visas by five percent of existing inward PTW migrant stocks, allocated across the bilateral source shares of those stocks. This is done in year 0 (2015) and has immediate economic effects beginning in 2016.

Model equations:

Initial MTW labor forces: M_s^0, M_d^0

Growth in bilateral labor flows: $E_{sd} = \alpha_{sd} * \nu * M_d^0$

Total outward movers: $E_s = \sum_d E_{sd}$

Total inward movers: $E_d = \sum_s E_{ds}$

Wage change at source: $W_s^1 = W_s^0(1 - \eta_s * (E_s/L_s))$

Wage change at destination: $W_d^1 = W_d^0(1 + \eta_d * (E_d/L_d))$

Income gain to movers: $\Delta Y_{st} = \delta * \sum_d (E_{sd} * (W_d^1 - W_s^0) * (1-\theta)^t)$ if $W_d^0 > W_s^0$

0 otherwise

Bilateral remittances: $\Delta R_{dst} = \rho * \Delta Y_{sdt}$

Efficiency loss source: $B = 0.5 * Es(W_s^0 – W_s^1)$

Efficiency gain destination: $D = 0.5 * E_d(W_d^0 - W_d^1)$

Fiscal externality source: $Z_s = -bt_s W_s^0 E_s$ Assume no double taxation of R

Fiscal externality destination: $Z_d = bt_d \delta W_d^1 E_d$ if $W_d^1 > W_s^0$

$Z_d = bt_d W_s^0 E_d$ otherwise

Spillover GDP N-N $I_d = i_{NN} W_s^0 E_{ds}$ USA to CAN and CAN to USA

Spillover GDP N-S $I_d = i_{NS} \sum_s W_s^0 E_{ds}$ USA or CAN to others

Spillover GDP S-N $I_d = i_{SN} \delta \sum_s W_d^1 E_{ds}$ Others to USA or CAN

Spillover GDP S-S $I_d = i_{SS} \delta \sum_s W_d^1 E_{ds}$ Others if $W_d^1 > W_s^0$

$I_d = i_{SS} \sum_s W_s^0 E_{ds}$ Others if not

Induced innovation benefits $N = i * I_d$ or $N = i' * I_d$

Gain to movers	$W_m = \Delta Y_{st} - \Delta R_{st}$
Welfare change source	$W_s = \Delta R_{st} - B + Z_s - H$
Welfare change destination	$W_d = D + Z_d + I_d + N$
Global welfare impact	$W = W_m + W_s + W_d$

Variable and parameter list:

	Variable or parameter	Range
M_d	Initial PTW migrants in destination	Varies by country
L_d, L_s	Initial PTW labor force in destination, source	Varies by country
ν	Percentage expansion of PTW circulation visas	.05 1-year
α_{sd}	Share of bilateral PTW flows from s to d	Varies by flow
η_d, η_s	Elasticity of labor demand in d, s	(-0.25, -0.35)
δ	Productivity differential	0.2, 0.5
ρ	Remittance rate	0.2, 0.32
θ	Wage catch-up per year	0.02
t_s, t_d	Average effective income tax rate in s, d	(0.15, 0.15)
b_s, b_d	Marginal excess tax burden in s, d	(0.2, 0.2)
i_{NN}	North-North productivity spillover	0.015
i_{NS}	North-South productivity spillover	0.03, 0.06
i_{SN}	South-North productivity spillover	0.0075
i_{SS}	South-South productivity spillover	0.02, 0.04
i	Domestic innovation productivity gains	0.04
i'	Global innovation usage gains	0.09

This paper was written by Keith E. Maskus, Professor of Economics at University of Colorado, Boulder. The project brings together more than 50 top economists, NGOs, international agencies and businesses to identify the goals with the greatest benefit-to-cost ratio for the next set of UN development goals.

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