MAURIZIO BUSSOLO
RAFAEL E. DE HOYOS
DENIS MEDVEDEV

Distributional Effects of the Panama Canal Expansion

Within the next three years, the output capacity of the Panama Canal will roughly double as a new set of locks is installed, enabling ships larger than the current Panamax standard to transit the canal. Several studies anticipate significant employment creation and growth effects of the canal expansion through increased domestic resource utilization and large multiplier effects.[1] This view, however, is not consistent with the long-standing characterization of Panama as a dual economy, where a dynamic services exports sector has few linkages with the rest of the economy. More important, the methodology of these studies cannot provide insights into the potential distributional consequences of the canal expansion—an aspect of crucial importance in Panama where inequality is a serious concern.

This paper adopts a methodological framework focused on the likely effects of the canal expansion on the distribution of income. The findings of the paper are obtained by linking a dynamic computable general equilibrium (CGE) model of Panama with a microsimulation framework based on a recent Panamanian household survey. The objective of the simulations is to contrast the counterfactual income distribution that would have resulted in the absence of the canal expansion project with the income distribution resulting from the canal expansion during both the construction and operation phases. Compared with earlier studies, this framework is much less suited for comprehensive growth analysis, especially in the near to medium term; on the other hand, it has the advantages of explicitly recognizing the intersectoral linkages in Panama's economy, clearly identifying the income sources of households, and providing a direct mapping of changes in macroeconomic aggregates to household welfare. Thus, this paper does not produce forecasts,

Bussolo, De Hoyos, and Medvedev are with the World Bank.
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1. Panama Canal Authority (2006b); IMF (2007).

but rather provides a consistent set of scenarios for the likely poverty and inequality consequences of the canal expansion.

The paper is organized as follows. The next section discusses the data and presents some background information on Panama and the canal shock. The paper then summarizes the model framework and subsequently discusses the macro- and microeconomic results of our simulations. The final section offers concluding remarks.

Background

Panama is often characterized as a dual economy, consisting of a dynamic, high-wage, export-oriented segment and a rigid, low-earning, domestic-oriented segment.[2] Service sectors dominate Panama's economy, accounting for 77 percent of total value added and 59 percent of total exports.[3] The canal sector is part of the dynamic, export-oriented services sector, accounting for one-fifth of Panama's exports, but only 6 percent of total value added and 0.5 percent of total employment. The sector operates as an enclave with few linkages with the rest of the economy: it exports all of its output, and its purchases of intermediate inputs (many of which are imported) are just 21 percent of its total production. Furthermore, its few workers are highly paid, with average earnings that are ten to twenty times the national average (see table 1).

There are several other elements to the duality of the Panamanian economy. Farm activities account for more than 21 percent of total employment, but just 8 percent of total value added, and the farm labor market is segmented from the market for nonfarm labor. Similarly, informal activities (excluding agriculture) contribute just 6 percent to total value added, yet 30 percent of workers earn their wages in the informal sector. Imports account for less than 10 percent of total purchases of agricultural products and services, while more than half of all demand for manufactured goods is satisfied through imports.

2. The data used in this exercise come from an updated 2003 social accounting matrix (SAM) for Panama as well as two household surveys for 1997 and 2003. The SAM was constructed specifically for the purposes of this paper, with particular attention devoted to the identification of labor and capital remuneration in both formal and informal activities (appendix B). Furthermore, considerable efforts were devoted to improving consistency between macroeconomic (SAM) and microeconomic (survey) data, although a full reconciliation of the two data sources remains beyond the scope of this paper. The SAM data are summarized in appendix A, which shows the structure of final demand and value added at the level of SAM accounts.

3. These and other shares reported in the text are calculated using the estimated SAM for Panama. The definition of service sectors excludes the Colon Free Zone but includes the canal services.

TABLE 1. Average Wages by Activity and Skill Level, 2003
In Panamanian balboas

Sector	*Unskilled*	*Skilled*
Agriculture	1,950	4,020
Nonagriculture	3,070	8,850
Informal (excl. canal)	1,700	1,750
Formal (excl. canal)	4,350	9,630
Canal	24,940	171,930

Source: The figures are computed using the Living Conditions Survey (Encuesta de Niveles de Vida, or ENV) 2003. Informality is defined as the employers and employees in firms with less than six workers who do not contribute to the social security system, nonprofessional self-employed workers, and household workers. A worker is classified as skilled when he or she has completed at least one year of secondary school.

The same dichotomous structure is evident in the distribution of income in Panama. At the bottom of the distribution, poverty is concentrated among households earning their incomes from agricultural activities, and practically all indigenous households are poor (see table 2). Despite the nearly 10 percent increase in real GDP per capita between 1997 and 2003, the poverty profile of Panama has hardly changed: the headcount ratio for extreme poverty declined slightly from 18.8 percent in 1997 to 16.6 percent in 2003. Taking into account the 12 percent population growth over the entire period, just 5,500 people escaped poverty in six years. When poverty is defined using the

TABLE 2. Incidence of Poverty among the Different Population Subgroups

Year and population subgroup	*Population*	*Per capita consumption (balboas)*	*Skilled population (%)*	*Extreme poverty (%)*	*Moderate poverty (%)*
1997					
Nonagricultural formal	970,524	2,551	32.0	3.8	17.7
Nonagricultural informal	1,095,408	1,860	22.0	10.5	29.8
Agricultural	461,532	859	4.9	40.1	70.6
Indigenous	205,675	330	2.3	86.3	95.4
Total	2,733,139	1,821	21.2	18.8	37.3
2003					
Nonagricultural formal	985,429	2,631	35.3	3.7	17.7
Nonagricultural informal	1,310,731	1,904	25.0	6.7	28.7
Agricultural	530,514	961	8.0	32.1	65.1
Indigenous	236,800	310	5.7	90.0	98.4
Total	3,063,474	1,851	23.9	16.6	36.8

Source: The figures are computed using the Living Conditions Survey (Encuesta de Niveles de Vida, or ENV) databases for years 1997 and 2003. The unit of analysis is the household; the welfare measure is consumption per capita. The extreme and moderate poverty lines are equal to 533 balboas and 953 balboas, respectively, which correspond to the official poverty lines used by the government of Panama. Informality is defined as the employers and employees in firms with less than six workers who do not contribute to the social security system, nonprofessional self-employed workers, and household workers. A worker is classified as skilled when he or she has completed at least one year of secondary school.

moderate poverty line, the picture is even worse: while the headcount ratio for moderate poverty hardly changed between 1997 and 2003, the absolute number of poor increased by more than 100,000 people. Finally, the indigenous community—already the poorest social group in Panama—experienced the most marked deterioration in living standards as their per capita consumption actually declined relative to the 1997 levels.

Table 2 shows that the fastest-growing labor group in Panama has been nonagricultural informal workers (an increase of 20 percent), while the number of people earning their primary income from formal activities hardly changed. Since wages in informal activities are significantly below formal earnings (table 1), the increase in the proportion of nonfarm informal population led to an expansion of moderate poverty among nonagricultural workers from 15.3 percent to 20.0 percent during this period. The period was thus characterized by what Ravallion, Chen, and Sangraula call the urbanization of poverty, with internal migration resulting in reductions in rural poverty, an increase in urban poverty, and little to no overall poverty effects.[4]

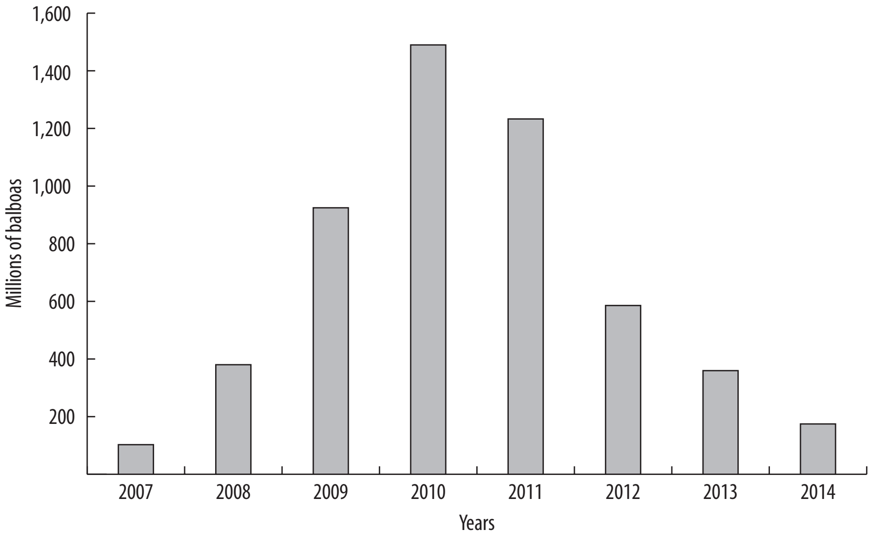
The expansion of the canal appears to be a large "shock" for Panama, with the total cost of the investment project estimated to reach 5.25 billion balboas (approximately 40 percent of GDP in 2003).[5] The year-by-year impact of the surge in investment is likely to be much smaller, however, because the construction activities are taking place over a seven-year horizon (figure 1). Furthermore, Panama's real GDP grew at an average annual rate of 8 percent a year between 2003 and 2010, and growth is expected to decelerate only slightly in the short and medium terms. Taking into account these growth projections, the additional investment in the Panama Canal is estimated at just 8 percent of GDP during the peak spending year of 2010, while the average annual spending over the entire construction period is less than 4 percent of GDP.

At the sectoral level, the canal expansion creates additional demand for only two types of activity in Panama: construction and capital goods. According to the initial structure of the investment demand, each additional balboa spent on canal investment generates 64 cents of additional demand for construction (which is almost entirely domestic) and 36 cents for capital goods (which are mostly imported). Although these sectors generate demand throughout the economy (the multiplier effect), the limited linkages of the

4. Ravallion, Chen, and Sangraula (2007).

5. This estimate is provided by the Panama Canal Authority in its report on the expansion of the canal. The full document is available online at www.pancanal.com/esp/plan/temas/plan-maestro.

FIGURE 1. Timeline of Expenditures for the Canal Expansion, 2007–14



Source: Panama Canal Authority (2006a , chap. 9).

canal with the rest of the economy restrict the ability of the investment spending to energize the entire economy.

A CGE Microsimulation Model for Panama

Given the vast differences in earnings across sectors and the semi-isolated status of the canal in Panama's economy, this paper adopts a structural macro-micro model to capture both the direct and indirect impacts of the canal expansion on the income distribution. The expansion directly affects those who receive an income from the construction and operation of the canal, but this group represents a fairly small portion of the total employment and includes very few poor and no indigenous people. Thus, the potential impacts of the canal expansion on the income distribution are likely to be mostly second-order, general equilibrium effects. These can be grouped into four major categories: (a) changes in real income growth, (b) changes in factor markets (namely, employment, wages, and rental rates), (c) changes in the prices of consumer goods, and (d) the use of the government receipts from the new canal.

The methodological approach of this paper can be best described as a two-step process. In the first step, a computational general equilibrium (CGE) model is used to create two scenarios, one with a new expanded canal and the other without. In the second step, the four sets of general equilibrium effects identified above are mapped to households in a microsimulation model. This procedure generates macro- and microeconomic counterfactuals that can then be used to estimate the effects of the canal expansion on the distribution of income.

The approach of this paper is based on ex ante macro-micro simulation methodologies developed in the recent literature: Bourguignon, Bussolo, and Pereira da Silva describe its advantages and drawbacks, while variants of this methodology have been used in various case studies.[6] The present paper belongs to the long literature on the welfare effects of large infrastructure projects. Duflo and Pande find that dam construction projects in India increase agricultural productivity in villages located downstream from the dam.[7] Using a difference-in-differences approach, Lokshin and Yemtsov find that improvements in school and road infrastructure increase welfare among the poor in Georgia.[8] Servén and Calderón use a variety of Generalized Methods of Moments (GMM) estimators on panel data of over 100 countries, covering the period 1960–2000; they show that infrastructure development can be highly effective for poverty alleviation.[9] Our approach differs from existing papers in two important ways. First, the CGE microsimulation model developed here allows us to capture the economywide effects of the canal expansion without losing the heterogeneous impacts on different households. Second, based on stylized facts, we assume that the canal is a separate sector with only marginal linkages with the rest of the Panamanian economy, so it has marginal, if any, effects on total factor productivity.

Macroeconomic Framework

The CGE model used in this paper is the World Bank's prototype single-country model.[10] Production takes place under perfect competition and constant returns to scale, and it is modeled in a nested constant elasticity of substitution

6. Bourguignon, Bussolo, and Pereira da Silva (2008). See also Bourguignon and Pereira da Silva (2003); Ferreira and Leite (2003); Chen and Ravallion (2004); and Bussolo and others (2008).

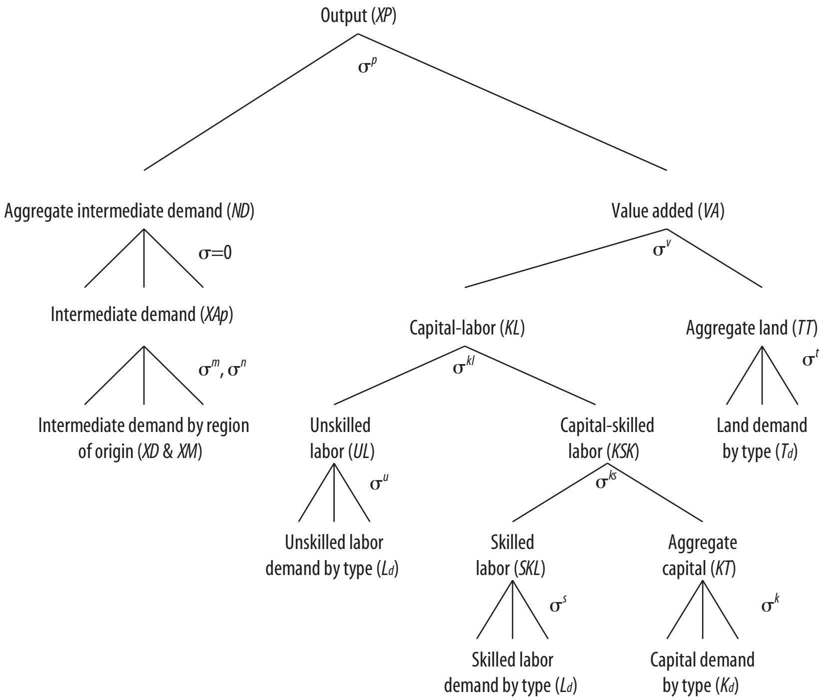
7. Duflo and Pande (2007).

8. Lokshin and Yemtsov (2005).

9. Servén and Calderón (2004).

10. See appendix D for model equations. Detailed model documentation and the user's guide are available in van der Mensbrugghe (2005b, 2005a).

FIGURE 2. Nested Production Structure



(CES) fashion to reflect various substitution possibilities across inputs (see figure 2). While the production nesting for the canal sector is similar to other activities, we assume that the canal uses a Leontief technology and employs a canal-specific capital stock. All labor and capital income accrues to the households, with the exception of capital income from publicly owned enterprises (such as the canal sector).

The model differentiates between formal and informal production activities, with the latter having no access to financial markets or public services. The output of these activities is transformed into consumed commodities by means of a transition matrix, which takes into account the fact that multiple activities can produce the same commodity (for example, construction services can be provided by both the formal and informal sectors) and that multiple commodities can be the output of a single activity.[11] Household

11. See appendix A for a full listing of commodities and activities in the model.

demand is allocated across commodities according to the linear expenditure system (LES), in which consumers maximize a Stone-Geary utility function subject to the disposable income constraint.[12] Other final demand agents—government and investment—use the CES expenditure system.

International trade is modeled using the nested Armington specification, in which consumer products are differentiated by region of origin and combined using CES functions.[13] World import prices are fixed, which means that any increase in import demand can be satisfied without affecting global prices (that is, a small-country assumption). On the supply side, producers allocate output to domestic and export markets according to a constant elasticity of transformation (CET) specification. With the exception of the canal sector, where Panama has monopoly power and therefore faces a downward-sloping demand curve, the export price elasticity of demand is infinite. Demand for canal services also responds to the growth in global trade by shifting outward in every time period.

The aggregate stock of capital is allocated across various sectors with a finite elasticity of transformation, resulting in imperfect capital mobility. Skilled workers are freely mobile throughout the economy, while the market for unskilled labor is segmented into farm and nonfarm categories. Within each segment, labor is perfectly mobile across activities, but mobility across segments is limited by a migration function that responds to changes in the farm/nonfarm wage premiums. The initial level of migration is calibrated at 2 percent of the farm sector labor force, consistent with the migration levels recorded in Panama over the 1997–2003 period. Although international migration is likely to be an important element in the dynamics of the Panamanian labor market, it is not considered in this analysis due to the difficulties of modeling this flow in a single-country setting. Labor mobility across formal and informal activities is not limited, but informal workers earn significantly lower salaries (on average, 20 percent of formal sector wages), giving rise to potentially large productivity effects when demand for one of the activity types rises. Finally, the model assumes no change in the degree of resource utilization, or fixed employment. This assumption is consistent with the available econometric evidence for Panama, which shows that the unemployment rate has been fairly stable at around 6 percent, even during economic upswings or downturns.[14]

12. See Deaton and Muellbauer (1980, chap. 3) for a detailed discussion of the LES demand system and Stone (1954) for the Stone-Geary utility function.

13. See Armington (1969).

14. See Galiani (2006).

The volumes of government current and investment spending (including investments in the canal) are fixed as shares of real GDP, as is the deficit (in real terms). Public revenues adjust to clear the government balance by means of a flexible household direct tax rate.[15] The investment-to-GDP ratio is fixed at the base year value, and a flexible marginal propensity to save out of household disposable income ensures that total saving equals total investment. The current account balance is fixed by the available quantity of foreign saving. The exchange rate is the numeraire, which means that domestic prices are determined relative to a fixed-cost basket of foreign goods.[16]

The model is solved in a recursive dynamic mode, in which subsequent end-of-period equilibria are linked with a set of equations that update the main macroeconomic variables. There are three determinants of real GDP growth in the model: labor supply growth, capital accumulation, and increases in productivity. The volumes of both types of labor grow exogenously at the growth rate of the working age population (ages fifteen to sixty-four), obtained from World Bank population forecasts. The capital stock in each period is the sum of depreciated capital from the period before and new investment. For all sectors, capital productivity remains fixed throughout the model horizon, while growth in labor productivity in the business-as-usual (BaU) scenario is calibrated to real GDP growth in the World Bank's medium- and long-term forecasts for Panama.[17] In all other scenarios, labor productivity is fixed in each period at the BaU level, and GDP growth becomes endogenous.[18] Thus, real GDP growth may differ from the BaU scenario due to faster or slower accumulation of capital or shocks to the productivity shift parameters, allowing the variations in GDP growth across scenarios to be directly attributed to the simulated policy reforms.

The Microeconomic Module: Linking Household Surveys to the CGE Model

The poverty and distributional effects of the canal expansion are estimated using a top-down approach. The top CGE-generated prices and labor real-

15. Although other assumptions about closing the government balance, such as adjustments in indirect taxes, increased borrowing, or reduced spending, are also plausible, choosing the direct tax rate as an instrument is a fairly neutral way (in an allocative sense) of restoring fiscal balance in case of a shock. It also simplifies welfare measurements since the incidence of making up the budgetary shortfall falls squarely on consumers (in contrast to indirect taxes, which may motivate producers to allocate a larger share of production toward exports that may be taxed at a lower rate).

16. We use the deflator of GDP at factor cost as a measure of movements in the real exchange rate.

17. Labor productivity growth in the canal sector is always exogenous.

18. Thus, in the absence of any shocks, the BaU GDP growth rate is reproduced exactly.

location are used to shock the bottom microeconomic module so that a counterfactual income distribution can be estimated. The model does not contain any explicit bottom-up feedback from the microeconomic module to the macroeconomic model. The following equations represent the core of the microeconomic module:

(1) $$W_h = f\left(Y_h, P_h\right) \cong \frac{Y_h}{P_h};$$

(2) $$Y_h = \sum_l \theta^{\ell}_{h,l} w_l + Y^o_h;$$

(3) $$P_h = p_f \theta_{f,h} + p_{nf}\left(1 - \theta_{f,h}\right).$$

The welfare of household *h*, W_h, is defined as a function of income and a household-specific price index, P_h. The income of household *h*, Y_h, is defined as the sum of labor remunerations,

$$\sum_l \theta^{\ell}_{h,l} w_l,$$

and an exogenous, nonlabor income, Y^o_h. For simplicity, a household-specific price index is defined as the sum of economywide food and nonfood price indexes weighted by the household's budget allocated to these consumption items. Welfare effects are approximated by the following general expression:

(4) $$dW_h = \frac{\partial W_h}{\partial Y_h} dY_h + \frac{\partial W_h}{\partial P_h} dP_h.$$

Therefore, changes in welfare are determined by changes in household income and the household-specific price index. In turn, changes in the household price index, dP_h, are solely determined by changes in the food and nonfood price indexes, keeping the budget shares, θ_f, constant. Changes in household income are determined by changes in labor remunerations, and they are allowed to vary as a result of changes in the returns to skilled and unskilled labor in the different labor market segments, Δw_l, and changes in the allocation of workers in the different labor market segments, $\Delta\theta^{\ell}_{h,l}$, including agricultural and nonagricultural sectors as well as formal and informal activities within the nonagricultural sectors. A new household welfare aggregate is computed by adding the exogenous household income to the sum of simulated labor incomes for each member of the household, given his or her skill endowments and sector of employment, and deflating the new total household income by the new household-specific price index. Based on the simulated welfare aggregate, a counterfactual distribution of income is generated and compared with the initial distribution.

A key issue in this modeling framework is the connection between the macroeconomic CGE part and the microeconomic module, which raises a major difficulty in terms of satisfactorily mapping the sources of income from the CGE model onto the microsimulation model. For example, in the CGE model, labor remunerations can be clearly distinguished from capital earnings, whereas in the microeconomic data, for the large group of self-employed people, incomes are a mix of labor and capital returns. For this group, we estimate an imputed wage and then classify the remaining amount as capital income (see appendix B for details). Furthermore, the microsimulation module defines an exogenous household income (Y_h^o) as all nonlabor income components like transfers, imputed rents, and capital remuneration. This exogenous income is not modified during the simulations. Thence, although we always aim for consistency between the macro- and microeconomic scales, the changes in capital remunerations predicted by the CGE are not reflected in the microeconomic data. The decision to treat capital remunerations as exogenous, thereby losing some macro-micro consistency, conforms to the limitation of household surveys for capturing incomes deriving from capital.[19]

A structuralist feature introduced in the model is the assumption of labor market segmentation. Some degree of labor segmentation is allowed between agricultural and nonagricultural sectors and, in urban areas, between formal and informal activities. The labor market segmentation assumption gives rise to wage differentials across labor market segments.[20] At the microeconomic level, workers are reallocated among agricultural, informal nonagricultural, and formal nonagricultural activities by means of a probit model in which the probability of switching sectors is estimated as a function of several personal and household characteristics.[21] Workers are allowed to switch between the

19. See Székely and Hilgert (1999).

20. The Chow tests for equality on the Mincer equation parameters between agricultural and nonagricultural sectors and formal and informal activities within urban areas were rejected at the 99 percent level of confidence. This is strong evidence supporting labor market segmentation.

21. See appendix C for the complete list of variables used in the microeconomic model and the results.

different labor market segments until the CGE-predicted labor allocation is achieved. For those workers who switch, a labor income is imputed on the basis of workers' observable characteristics and the associated returns in the receiving labor market segment.

The top-down approach used here takes into account important sources of household heterogeneity, such as the structure of income by labor segment and the composition of consumption by commodity—the various thetas in the above equation. In other words, although only a few variables link the macroeconomic and the microeconomic aspects, these shocks will have a different welfare impact across households. Additionally, allowing for full heterogeneity means that in the new simulated distribution, households, as well as individuals, can be identified according to the complete set of socioeconomic characteristics recorded in the survey. It is thus easier to identify a specific characteristic (such as region of residence, employment status, gender, education, or age) that may strongly correlate with larger-than-average losses from the canal expansion and then use this information to target compensatory measures.

Macroeconomic and Distributional Impacts of the Canal Expansion

This section contrasts a business-as-usual (BaU) scenario with a canal expansion scenario to assess the potential effects of the canal expansion project on real GDP and its components, the real exchange rate, the labor markets, and the government budget. The dynamic macro-micro simulation framework used here is not a forecasting tool, so the emphasis is mainly on the differences between the BaU and the canal expansion scenario. These differences tend to be robust in that they do not change much with variations in the assumptions and dynamic paths of the exogenous variables used in the BaU scenario. In other words, the value added of the modeling exercise does not consist of forecasting the future level of specific variables, but rather in showing how those levels are changed by the expansion and operation of the canal, other things equal.

Macroeconomic Results: Business-as-Usual Scenario

The behavior of macroeconomic variables in the BaU scenario is summarized in table 3. The results are reported separately for two periods, 2003–14 and 2014–20, with the first period characterized by rapid growth in real income and

TABLE 3. Macroeconomic Variables

		Average annual growth rate (%)			
	Initial level (bn lcu)	*BaU*		*Canal expansion*	
Variable	*2003*	*2003–14*	*2014–20*	*2003–14*	*2014–20*
Real GDP at market prices	12,933	5.36	3.06	5.37	3.68
Private consumption	8,016	5.40	3.03	5.42	3.92
Public consumption	1,807	5.36	3.06	5.36	3.06
Investment	2,457	4.92	2.89	5.33	3.08
Noncanal investment	2,120	5.36	3.06	5.37	3.68
Canal investment	87	5.36	3.06	12.86	−2.36
Stock changes	249	0.00	0.00	0.00	0.00
Exports	4,425	5.32	3.54	5.22	4.22
Imports	−3,771	5.14	3.44	5.26	4.15
Real Income per capita	3,790	3.81	2.02	3.83	2.60
		End-of-period values (for the corresponding periods)			
Real exchange rate (index number)	1.00	1.012	1.066	1.015	1.108
Welfare (EV)				25	1,266
Trade-to-GDP (percent)	63.4	61.8	59.6	61.5	58.0
Food CPI (index number)	1.000	1.011	1.050	1.014	1.075
Nonfood CPI (index number)	1.000	1.011	1.062	1.013	1.099

Source: Authors' computations.

the second period exhibiting a marked slowdown to a more sustainable, lower growth path.[22] In the second period, export growth slows relative to imports as the real exchange rate experiences a more marked appreciation. This is determined mainly by the dynamics of productivity growth, which drives the strong growth performance during the first period and decelerates rapidly in the later years.[23] In the high-growth period, increases in productivity help keep output costs down and buttress the competitiveness of Panamanian producers vis-à-vis foreign firms. During the transition to slower growth, smaller annual improvements in labor productivity imply that more workers are needed for a given increase in output, driving up labor costs and eroding the competitiveness of Panamanian products versus foreign-made goods. Finally, as explained in the previous section, public consumption and public and private investment remain fixed as a share of real GDP in every year of the BaU scenario.

The evolution of factor markets matters not only for the external competitiveness of Panama, but also for its pattern of sectoral specialization. Several

22. In the canal expansion scenario, the first period also corresponds to the construction phase and the second period to the operation phase.

23. The model assumes that all technological change is Harrod neutral, that is, labor augmenting.

TABLE 4. Factor Markets

		Annual growth rate (%)			
		BaU		*Canal expansion*	
Factor	*Initial level 2003*	*2003–14*	*2014–20*	*2003–14*	*2014–20*
Wages					
Unskilled wage	2.7	3.5	2.1	3.6	3.3
Nonfarm unskilled wage	3.1	2.8	1.7	2.9	3.0
Farm unskilled wage	1.9	4.9	3.3	5.0	3.9
Skilled wage	8.7	4.3	5.7	4.3	8.2
Capital					
Formal capital real rent (index)	1.0	−0.4	−2.2	−0.4	−2.6
Informal capital real rent (index)	1.0	0.9	−3.8	0.9	−5.8
Canal capital real rent (index)	1.0	−0.1	−1.1	−0.2	0.3
Labor					
Total labor supply	1,178.0	1.6	1.3	1.6	1.3
Unskilled labor	713	1.6	1.3	1.6	1.3
Unskilled farm labor	236	−0.4	−0.4	−0.4	−0.5
Unskilled nonfarm labor	477	2.5	1.9	2.5	2.0
Unskilled formal nonfarm labor	217	2.2	3.2	2.3	3.5
Unskilled informal nonfarm labor	260	2.7	0.8	2.6	0.6
Unskilled migration	5.2	−2.0	−1.6	−2.0	−0.8
Skilled labor	465	1.6	1.3	1.6	1.3
Skilled formal nonfarm labor	365	1.7	1.8	1.7	1.8
Skilled informal nonfarm labor	84	1.3	−0.9	1.2	−1.0

Source: Authors' computations.

major trends are observed in the BaU scenario and summarized in table 4: an acceleration of skilled wage growth relative to the wages of unskilled workers, a gradual reduction in farm employment, a pronounced decline in capital rental rates during the second period, and a reduction in the share of formal activities during the first period, followed by increased formalization in the second. The increasing skill premium can be largely explained by the differences in labor supply and labor demand. The scenarios considered in this paper do not incorporate increases in the average educational attainment over time, which means that the stock of both skilled and unskilled workers grows at the same rate as the working age population. On the other hand, demand for skills rises over time as Panama shifts out of unskilled-intensive activities like agriculture and into more skill-intensive manufacturing and services.[24] This

24. The contribution of agriculture to total output declines from 7.3 percent in 2003 to 6.2 percent in 2014 and to 5.6 percent by 2020.

transition is consistent with econometric evidence that food income elasticities tend to be below one; it also results in a relative increase in demand for skilled labor and a widening of the skilled wage premium.

The structural shift out of agriculture is also driven by falling farm employment, which declines at an average rate of 0.4 percentage point per year. This is consistent with the experience of Panama between 1997 and 2003, when the rates of worker migration to nonagricultural activities outpaced the growth rate of the farm labor force. As a result of the relative labor scarcity in agriculture, farm wages actually grow faster than nonfarm wages in the BaU scenario, reducing the nonagricultural wage premium from 58 percent in 2003 to 15 percent in 2020.

The changes in consumer prices (reported in the bottom part of table 3) are mainly determined by the trends in agricultural production and the demand for food products. Between 2003 and 2014, slower-than-average growth rates of farm output and demand for agricultural goods offset each other, resulting in similar changes in food and nonfood prices. In the later period, slower growth in food demand outweighs smaller contributions of agriculture to total supply, and the food consumer price index (CPI) increases less than the CPI for manufactured goods and services.

The changes in the share of formal activities and the behavior of capital rental rates are both linked to the slowdown in growth in the later part of the model horizon. Moving to a lower growth path means that the stock of capital accumulated during the period of high growth is too large, necessitating some shedding of capital (through accelerated depreciation) and also triggering a decline in the rental rates. Since formal activities tend to be much more capital intensive than informal activities (see appendix A), access to cheaper capital benefits the former more than the latter and leads the transition toward increased formalization. The opposite trend takes place in the early period, when formal activities have a cost disadvantage relative to the informal sector when the prices of skill-intensive financial services and public administration rise faster than the economywide average.

Because public services are much more skill intensive than the economywide average (see appendix A) and skilled wages grow faster than unskilled wages (table 4), over time the government must increase its revenue collections to be able to fulfill its service delivery commitments. In our scenarios, this is accomplished by a combination of raising direct taxes (to finance the rising recurrent costs) and increased foreign borrowing (to finance capital projects, including investments in the canal sector). As a result, disposable income per capita grows at a slightly slower rate than real GDP per capita.

Macroeconomic Results: Canal Expansion Scenario

In the second scenario, public investment in the canal is accelerated according to the Panama Canal Authority's schedule (figure 1) and is financed by borrowing on the international capital markets. During the construction phase, which takes place between 2007 and 2014, the yearly growth rate of the investment in the canal more than doubles (table 3), while canal output remains the same as in the BaU scenario.[25] In the operation phase, when the new sets of locks come online in 2014, the output rises to twice the BaU levels.

In the construction phase, the growth rates of real GDP and private consumption barely accelerate relative to the BaU scenario. Therefore, unlike the views expressed by the Panama Canal Authority and the International Monetary Fund (IMF), the construction of an expanded canal has a very small growth impact in our model.[26] This outcome can be explained by the following reasons. First, although employment demand in the construction sector goes up, new jobs in this sector amount to just 4 percent of the total unskilled employment and around 2 percent of skilled employment even during the peak investment year of 2010.[27] The simple averages of the employment gains during the construction years are 0.9 percent and 0.4 percent for the unskilled and skilled segments, respectively, which means that despite a large increase in demand for construction services from the canal project, relatively few jobs are created from the economywide perspective. More important, the new jobs in the construction sector are filled by workers leaving jobs in other sectors. This assumption of a fixed unemployment rate is the main determinant of the lack of large growth effects during the canal expansion. The assumption is consistent with the rigidities in Panama's labor market and the fact that employment has been very slow to rise even during periods of economic boom, as documented by Galiani, but it is at odds with the view of the Panama Canal Authority and the IMF, which expect employment to rise by 2–4 percent from the 2003 levels.[28]

The second reason that our model does not generate significant growth effects of the construction phase is the assumption that the capital stock accumulated during the canal expansion cannot generate any additional income flows until construction is completed in 2014. Therefore, factor endowment

25. The growth rate of canal investment reaches almost 13 percent, up from 5.4 percent in the BaU.

26. Panama Canal Authority (2006b); IMF (2007).

27. These percent increases include new informal construction jobs.

28. Galiani (2006); Panama Canal Authority (2006b); IMF (2007).

in the first period of the canal expansion remains the same as in the BaU scenario, and if the canal investment does not generate any productivity spillovers, the only source of the marginal real income gains shown in table 3 is the reallocation of resources into more productive sectors of the economy. This is indeed the case here, as table 4 shows that the demand for labor in the formal sector—where workers are paid five times more, on average, than in the informal sector (table 1)—accelerates in the canal expansion scenario relative to the BaU.

Even if real income growth remains largely unaffected during the construction phase, the increase in investment spending can have other relevant macroeconomic consequences. Among these, the risk of Dutch disease effects is frequently highlighted. The argument is as follows. If all expansion-related financing is obtained in the form of foreign borrowing, as simulated here, the larger inflows of foreign currency increase domestic demand, specifically investment demand for the expansion of the canal. This additional domestic demand is satisfied by increased imports and increased domestic production of nontradable goods (mainly construction services). Import prices are unaffected by the increased demand in Panama, whereas nontradables prices, together with factor prices, will rise. This relative price shift results in a real exchange rate appreciation which, in turn, has a negative impact on export sectors. When we compare the canal construction phase with the first period of the BaU, all these effects—stronger increases in factor and goods prices, faster real exchange rate appreciation, larger imports, and decreased exports—are observed in the model results, but their magnitude is rather small.[29] In particular, while unskilled wages accelerate in the canal construction phase relative to the BaU conditions (table 4), food prices (which represent a larger share of total consumption for poor households) also increase faster than in the BaU (table 3). This makes the poverty impacts of the canal construction phase ambiguous. At the same time, although the direction in poverty changes is unclear from the macroeconomic results, the canal construction project is almost certainly not having any direct poverty alleviation effects, and its indirect effects through changes in employment, factor prices, and goods prices are also likely to be limited.

29. The small magnitude of these effects is, in turn, explained by the limited size of the increased investment in the canal and the same arguments used above on the minor effects on GDP growth. In addition, the leakages through imports are quite relevant in the canal project shock: a large share of increased nonconstruction investments is satisfied by imports. Finally, the intersectoral mobility of factors, which are quite high in the model assumption, helps to reduce factor price inflation and thus also moderates goods price increases.

The impact of public spending on poverty reduction during the construction phase is similarly small. Due to the acceleration in growth of prices and wages in the construction phase (the Dutch disease described above), the cost of providing public services during this period rises relative to the BaU scenario. As a result, the government requires higher direct tax revenues, which are obtained via a small increase in the household income tax rate.[30] This increase explains why per capita income accelerates less than real GDP during the construction phase (table 3), although the poverty impacts are likely to be very mild, given the small aggregate magnitude of the change.

What about the operation phase? According to background studies by the Panama Canal Authority, the expanded canal will become operational in 2015. At this date in the simulation model, the capital stock and the output of the canal sector more than double. Current available projections indicate that there will be enough demand for the expanded canal, but much less is known about the price elasticity of this demand.[31] In this particular market, Panama clearly operates in a monopolistic position, which is reflected by a downward-sloping world demand curve for canal services. However, demand also shifts outward from one year to the next, following the increasing trend of global trade. Depending on the relative sizes of the price elasticity of the demand for canal services and the outward shifts of this demand curve, the dynamic path of the canal fees will be either growing or decreasing. Statistics for recent years show that Panama has been able to raise the transit fees without affecting demand.[32] The current simulation assumes that this trend continues in the future even with an expanded canal.

A major consequence of the new locks coming online is the acceleration in the yearly growth rate of real GDP to 3.7 percent from 3.1 percent in the BaU scenario. There are two major reasons for faster income growth during the operation phase. First, the now-larger (canal-sector-specific) capital stock raises the factor endowment of Panama and generates new income through higher canal capacity and increased fees. Second, a boost in total factor productivity occurs as workers move from less productive (and lower-paying) occupations into the canal sector, where both productivity and wages are high (table 1). Furthermore, additional income growth generates more

30. For example, the 2014 direct tax rate rises from 8.82 percent in the BaU to 8.85 percent in the canal expansion scenario.

31. See Panama Canal Authority (2006a, 2006b) and IMF (2007).

32. See Guillermo O. Chapman, "Panama Monthly Report: Growth and Its Discontents," *Latin Source,* 30 May 2007.

demand for manufactured goods and services (relative to agriculture) and encourages worker migration into nonfarm occupations, where productivity tends to be higher.

The canal sector is skill intensive, and the additional demand for skilled workers resulting from its expanded operation generates a significant increase in their wages (see table 4). The canal sector can afford to pay higher wages because higher wage costs are passed on through higher canal fees, with little or no effect on net income. Higher skilled wages generate labor income gains, which in turn increase domestic demand and benefit all workers.[33] For these reasons, the wages of unskilled workers also rise, but the rate of increase in the earnings of unskilled employees falls short of the acceleration in skilled wages. As a result, the skill premium widens from 329 percent in 2020 under the BaU scenario to 360 percent in the same year under the canal expansion scenario. Even before we move to microeconomic analysis, these results already indicate that the growth dividends of the canal operation are likely to be unequally distributed, with the larger share of the gains accruing to the better-off segments of the population.

The wage pressures in the canal operation phase push up domestic resource costs and are reflected in the real exchange rate appreciation shown in table 3. Remarkably, the real exchange rate differential between the BaU and the expansion simulations is much higher in the operation phase than in the construction phase. In a way, the expanded operations of the canal sector can be thought of as the discovery of a new natural resource for which there is an increasing world demand. The booming of canal service exports, however, has some unfavorable effects for the other tradable sectors. During this phase, other export sectors record lower growth rates, and import-competing domestic sectors struggle against cheaper imports. As a result, Panama specializes further in exporting canal services.

The additional real exchange rate appreciation and rising domestic costs of the canal expansion scenario are also evident in faster growth of consumer prices (table 3). Although the prices of both food and nonfood commodities accelerate relative to the BaU scenario, the increase in the nonfood CPI is twice the increase in food prices. This is consistent with higher income elasticities for nonfood products, as well as the higher skill content of nonagricultural goods. Unlike the changes in factor returns, the trends in consumer

33. Workers in the canal sector enjoy a large exogenous premium vis-à-vis the other sectors. Increased employment in the canal and rising wages thus combine to produce a very significant gain in labor income for the household sector.

prices are likely to attenuate the tendency of the expansion scenario to favor richer parts of the population because food prices (the main consumption item of the poor) increase less than the economywide CPI.

Turning now to the government accounts, two offsetting trends take place in the canal operations phase. On the one hand, the faster pace of income and wage growth in the operations phase (relative to the BaU scenario) means that public expenditure must rise significantly in order for the government to maintain the same level of public service delivery as in the BaU scenario. On the other hand, a large part of the increased expenditure can be funded by higher canal revenues, as well as increased indirect tax collection. As a result, the government can increase the size of its income transfers to households by 273 million balboas in 2020 (through decreased direct taxation). This transfer leads to faster growth of household disposable income and contributes to the sizable welfare gains observed in this scenario (table 3). The revenue effect also has potentially important distributional effects: while in the macroeconomic part of our model, we assume that the gains are distributed uniformly across all households, our microeconomic model allows for exact targeting of any potential public program (for example, similar to the existing cash transfer program) that might seek to redistribute the canal revenues to the poorer segments of the population.

Distributional Impacts of the Canal Expansion

As described above, two quite different periods characterize the BaU scenario. During 2003–14, strong growth and minor distributional effects result in significant poverty reduction. Conversely, sluggish growth combined with an increase in inequality led to almost no change at all in the incidence of poverty between 2014 and 2020 (see table 5). Neither of the two periods is characterized by a strong labor reallocation: movement of workers out of agricultural activities continues at a slow rate, and informality in nonfarm employment stabilizes at around 40 percent.[34]

The distributional effects of the different pattern of growth of the two periods are graphically summarized by the growth incidence curves (GICs)

34. The CGE model does not explicitly account for rural-to-urban (or geographic) migration of workers, but only for agricultural to nonagricultural (or intersectoral) labor reallocation. Only the first type of workers' movement can be defined as internal migration and precisely linked to urbanization. However, given the high correlation (0.58) between working in nonagricultural sectors and being located in urban areas, we sometimes use the terms sectoral reallocation and urbanization interchangeably in the main text.

TABLE 5. Poverty and Distributional Effects under the BaU and Canal Scenarios

Welfare indicator	*Observed 2003*	*BaU*		*Canal expansion—BaU*	
		2014	*2020*	*2014*	*2020*
Average real income	2,490	3,219	3,725	6	243
Poverty headcount ratio (%)					
Extreme[a]	16.6	12.9	13.3	–0.1	0.0
Moderate[a]	36.8	28.3	27.5	–0.1	–0.3
Poverty gap (%)					
Extreme[a]	6.4	5.2	5.4	0.0	0.1
Moderate[a]	15.2	11.9	12.0	0.0	0.1
Gini coefficient	56.8	57.7	59.8	0.0	0.7

Source: Authors' estimation based on data from the World Bank's 2003 Living Standards Measurement Study (LSMS) and the results of the CGE microsimulation model for Panama.

a. The extreme and moderate poverty lines are equal to 533 balboas and 953 balboas, respectively, which correspond to the official poverty lines used by the government of Panama.

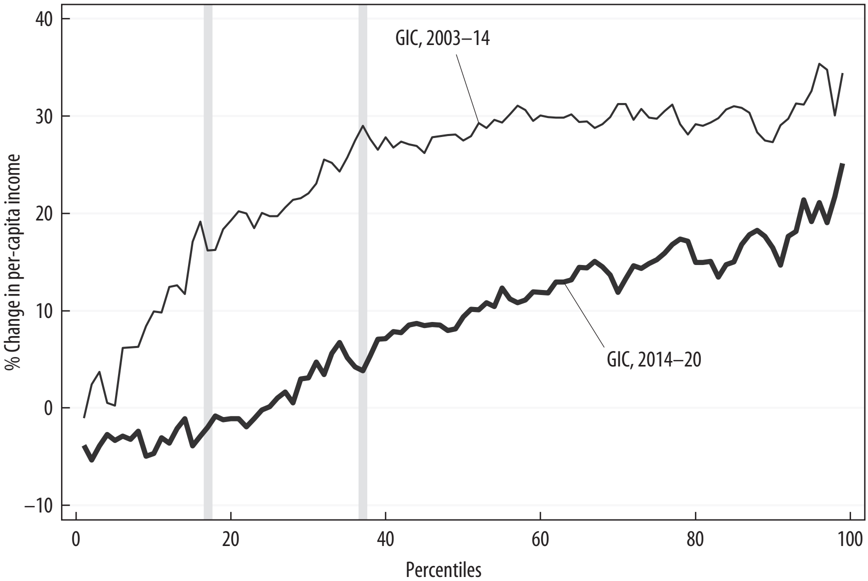
shown in figure 3.[35] In the BaU scenario, real average incomes for the median household in Panama cumulatively increase by 27.5 percent between 2003 and 2014. This gain is not evenly distributed: the income of the bottom 10 percent of the distribution rises only 4.3 percent, on average, versus 32 percent for households in the top 10 percent of the distribution.

The effect is even more regressive in the BaU scenario during the second period. The median income increases 9.4 percent with respect to 2014, but incomes at the bottom 10 percent of the distribution decrease 3.7 percent while the incomes of the richest 10 percent of the population rise almost 20 percent. The regressive income effect shown by the GICs in figure 3 is explained by an increase in the wage gap between skilled and unskilled workers. In both subperiods, real wages of unskilled workers in nonagricultural sectors—the largest labor segment—experience the slowest growth rate. As a result of the increase in the wage differentials, household income distribution deteriorates, as indicated by the increase in the Gini coefficient reported in table 5.

Labor reallocation between agricultural and nonagricultural sectors and, within the latter, between formal and informal activities also plays a relevant role in reshaping income distribution. In the BaU scenario, the urbanization process continues throughout the period 2003–20, with the share of workers

35. The GIC shows the changes in welfare along the entire income distribution, thus capturing the growth and distributional components of overall welfare changes in a single graph. For a detailed description of the properties characterizing the growth incidence curves, see Ravallion and Chen (2003).

FIGURE 3. Growth Incidence Curves (GICs) for the Business-as-Usual Scenarios[a]

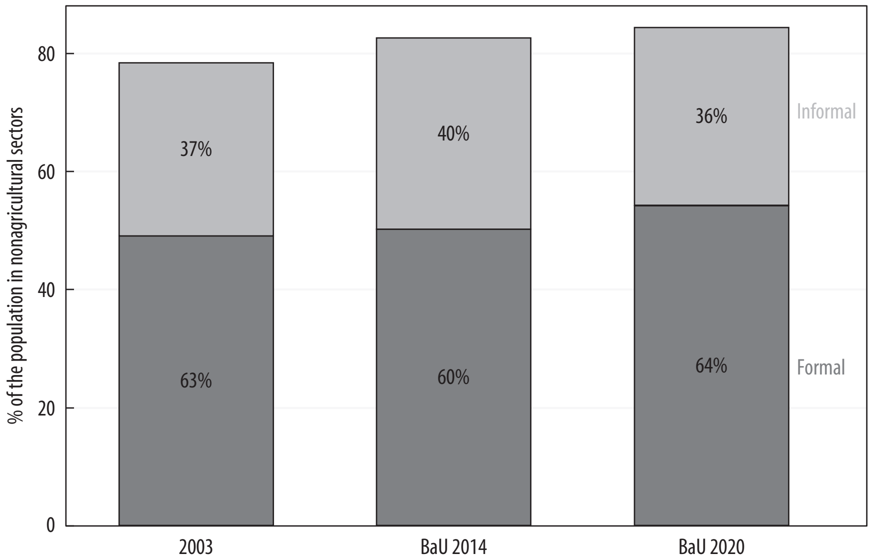


Source: Authors estimations.
a. Vertical lines represent the percent of the population under extreme and moderate poverty, respectively.

in nonagricultural activities increasing from 78.5 percent in 2003 to 82.7 percent in 2014 and 84.4 percent in 2020 (figure 4). Movement of unskilled workers out of agricultural activities creates pressure for job creation in the nonfarm, mainly urban, segment of the economy. If not enough formal jobs are created, informality increases, and urbanization may thus be followed by a higher incidence of poverty in the nonfarm urban centers. This could happen in Panama between 2003 and 2014: although overall poverty is falling, the increased informality that accompanies the urbanization process reduces average incomes and increases poverty among nonfarm informal households. This trend is reversed in 2014–20, when informality is reduced from 40 percent to 36 percent, despite the continuous rural-to-urban migration of unskilled workers.

The welfare effects discussed so far are those that would take place between 2003 and 2020 under the BaU scenario. Under the canal expansion scenario, model simulations show that the welfare differentials between the BaU and the expansion scenarios are negligible during the construction phase and rather small during the first six years of the operation phase.

FIGURE 4. Sectoral Reallocation: Urbanization with Low Creation of Formal Jobs

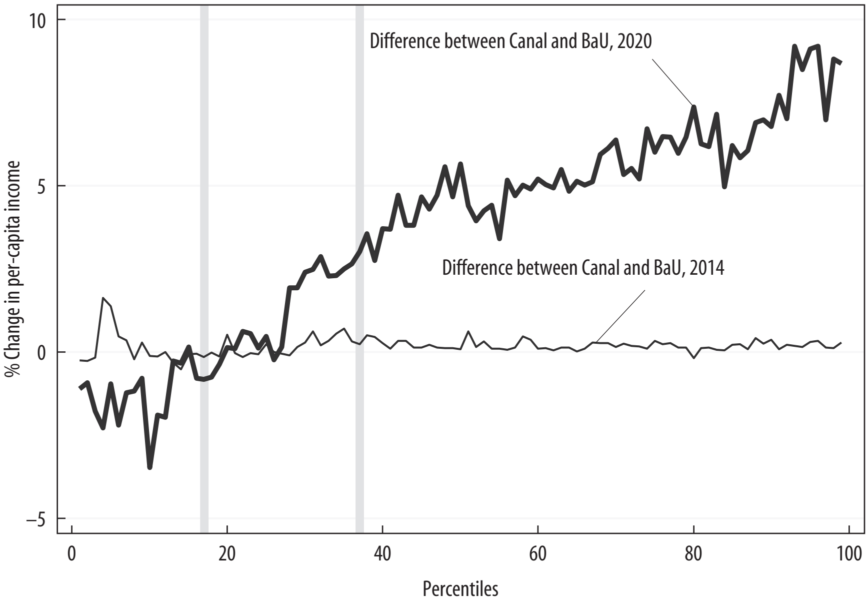


Source: Authors' calculations.

The moderate real income gain of six balboas, on average, during the construction phase (table 5) is explained by a rise in wages and a reallocation of workers out of agricultural sectors and into formal activities. As a consequence of the canal construction, almost a thousand workers move out of agricultural sectors, and more than 3,000 abandon informal occupations. All the movers enjoy considerable welfare gains; however, due to the small size of this group the overall distributional effect is negligible, as demonstrated by the lack of change in the Gini coefficient and the flat growth incidence curve of figure 5. Aggregate poverty declines marginally due to a relative increase in farm wages as a consequence of out-migration from the agricultural sector.

The operation phase is characterized by a larger average real income gain, of about 243 balboas, and a noticeable increase in inequality. About 10,000 individuals (or 0.3 percent of the population) escape moderate poverty, with 10 percent explained by labor reallocation and the rest accounted for by increased wages for unskilled workers in urban areas. The poverty gap increases, however, meaning that poorer individuals are negatively affected and their incomes fall further away from the poverty line.

FIGURE 5. Growth Incidence Curves (GICs): Canal Expansion versus BaU, 2014 and 2020[a]

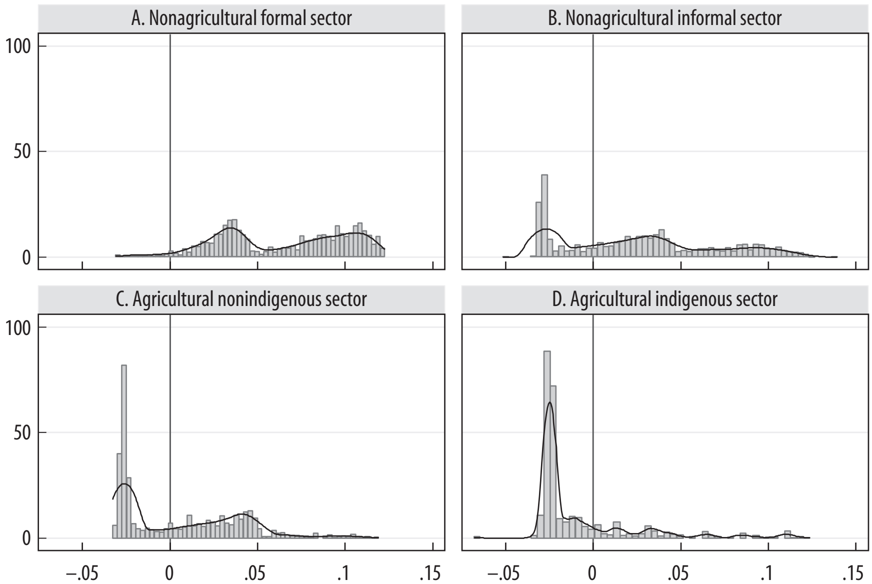


Source: Authors' estimations.
a. Vertical lines represent the percent of the population under extreme and moderate poverty, respectively.

The increase in inequality during the canal operation is underpinned by a contraction in real income for the poorest groups of the society. On the one hand, households in the left tail of the income distribution (mainly rural and indigenous communities) are mostly detached from the dynamic formal sectors in urban areas. For these households, labor remuneration accounts for as little as 30 percent of total income; the remainder is made up of remittances, government transfers, imputed rents, pensions, and other transfers, none of which directly benefit from increased output of the canal or its related activities. On the other hand, rising goods prices cause an increase in the cost of a consumption basket for these households (see the last two rows of table 3).[36] Consequently, as illustrated in figure 5, households in the left tail of the distri-

36. This result should be taken with caution since we are assuming that consumption baskets are fixed although prices are changing. Moreover, the household-specific price index that we are using allows only for differences in the shares of food to nonfood expenditures between households. One would expect that the basket of food consumed by the poor would differ substantially from the basket of food consumed by the nonpoor.

FIGURE 6. Distribution of Real Income Changes in 2020: Canal Expansion versus BaU, 2020



Source: Authors' estimations.
a. The horizontal axis represents the percent difference between households' per capita income under the canal expansion and BaU scenarios in 2020.

bution (the 17th percentile and under) suffer a real income loss of 1.3 percent relative to the BaU scenario.[37]

Figure 6 shows the distribution of changes in real income by population group. This figure clearly illustrates that, notwithstanding the positive average change of five balboas, a large share of people in the indigenous group experience losses under the canal expansion scenario. This contrasts with the distribution of the gains and losses for people occupied in formal nonagricultural sectors (panel A). For this latter group, higher density is concentrated in the positive portion of the horizontal axis; that is, the majority of the group gains from canal expansion.

37. The real income of the families under extreme poverty would increase 1 percent under the assumption that the real value of the exogenous components of income remains constant. In other words, if the government were to compensate for the increase in prices brought about by the canal operation, everybody would benefit. Nevertheless, the regressive effects of the canal would remain (we discuss compensatory measures below).

Poverty Effects of Potential Redistribution Policies

The model's results show that the canal expansion will have a positive effect on average incomes, including government revenues. However, the distributive effects of the canal expansion are adverse, not only increasing inequality, but reducing welfare among the poorest households. The unfavorable distributional effects brought about by the canal expansion could be offset by implementing redistribution policies or strengthening existing ones. By 2020, the government of Panama will receive an extra 273 million balboas as a direct result of increased canal transit. To put this figure in perspective, if the government wanted to eliminate extreme poverty in 2003, it would have to transfer 104 million balboas to the poorest families; eradicating moderate poverty would cost 445 million balboas. Thus, the extra government resources generated by the canal expansion are far from trivial. In 2020, with the canal extension in operation, eliminating extreme and moderate poverty will require a total transfer of 90 million balboas and 350 million balboas, respectively.

To illustrate the poverty effects of a redistribution program, we simulate a case in which the entire excess revenue of the canal (273 million balboas) is transferred to the poorest families in Panama. The transfers are equal to the gap between per capita household consumption and the moderate poverty line; the families are sorted from the poorest to the richest and the transfers follow this order and continue until the 273 million balboas are fully allocated. Under this simplistic redistribution policy scenario, extreme poverty would be completely eliminated, and the incidence of moderate poverty would be reduced to 13.2 percent of the population (see table 6). In this hypothetical redistribution program, the poorest 66,425 families in Panama (including 438,766 individuals or 14 percent of the population) receive an annual transfer equal to 4,128 balboas.

TABLE 6. Welfare Effects after Redistributing the Canal's Revenues

		Poverty headcount ratio[a]		
Scenario	*Average real income*	*Extreme*	*Moderate*	*Gini coefficient*
Transfer equal to the moderate poverty gap (no leakage)	3,842	0.0	13.2	56
Transfer equal to the moderate poverty gap (with admin. costs and 20% leakage)	3,842	3.7	18.0	57

a. The extreme and moderate poverty lines are equal to 533 balboas and 953 balboas, respectively, which correspond to the official poverty lines used by the government of Panama.

This redistribution program is sufficient for a massive reduction in inequality of three Gini points; nevertheless, this large equalizing effect reflects the assumptions that the redistribution policy has no administrative costs and that targeting is perfect (that is, there is no leakage of resources, such that no individual among the nonpoor group benefits from the program). A more realistic scenario would take into account administrative costs and some degree of leakage of resources. For instance, in Panama's pilot conditional cash transfer program, *Red de Oportunidades,* 5 percent of the program's total 30 million balboas budget is expected to be spent on administrative costs. If we apply an administrative cost of 5 percent of the total budget and a leakage of, say, 20 percent, the resources available for transfer are still 204 million balboas, enough to alleviate most of Panama's poverty. Under this more realistic scenario, extreme poverty is almost eliminated and moderate poverty is reduced to 18 percent of the population (see table 6).

Caveats and Robustness: A Brief Discussion

Modeling the impact of a large future infrastructure project such as the Panama Canal at both the macro- and microeconomic levels is an extremely complicated exercise. Although we have made every effort to embed as much realism as possible while still keeping model results tractable—and the resulting effort represents the best available methodology to date for carrying out this type of analysis—the results come with a set of important caveats. They should not be interpreted as forecasts, but rather as ceteris paribus scenarios where many elements of the economy were left unchanged for tractability and where some simplifying assumptions were deemed necessary.

Two key assumptions were maintaining the composition of skills constant across scenarios and incorporating full employment of factors. With regard to the former, although the model horizon is long enough to allow some individuals to respond to changing wage levels by investing in skills building, modeling such a response is fraught with difficulties. First, if individuals exit the labor market to acquire new skills, growth would suffer in the interim as the labor supply would decline. The decline in growth, in turn, would generate a fall in demand for skill-intensive products, which would limit somewhat the pressure on skilled wages. Second, opportunities must be available to allow an economically significant number of workers to upgrade their skills. This would normally imply an expansion in the public provision of educational services and training, but such a supply response would take time and would also have to be financed. Depending on the financing vehicle, this could imply higher rates of taxation or some crowding out of private investment, both of which would dampen growth and slow the expansion of skilled wages. Given the many additional assumptions required to incorporate such a supply response, the paper does not explicitly model this possibility. However, if a sufficient number of workers were able to upgrade their skills—with limited negative spillovers for growth in the interim period—the adverse distributional effects described in this paper would be lessened.

With regard to the full employment assumption, the model could accommodate a solution with unemployment. However, we opted for a full employment closure because of the empirical evidence on the relative stability of the unemployment rate and because the economy of Panama has been growing (even before the construction phase) above its 6 percent potential growth rate, such that the recent 6.5 percent unemployment rate (in 2007–10) can be considered structural and insensitive to increases of demand.[38] To check how our results would change with unemployment, we ran a version of the CGE model where wages are fixed and additional demand is met with additional employment, a sort of pure multiplier model. In this setup, the construction phase would create just 0.2 percent more employment (for both skilled and unskilled workers) than the BaU scenario.[39] In this case, wages do not rise, so there are incentives for firms to substitute other inputs for labor, compatibly with a given technology. As explained above, canal construction generates demand for construction services, but also large leakages through imports, so this small employment multiplier is not surprising. The operation phase generates a slightly larger effect, with employment increasing by 2.5 percent by the end of the projection period. What can be expected of these quantity changes in terms of income distribution? Assuming that unemployed workers are in the lower tail of the distribution, a reduction of unemployment may have some equalizing effect. These effects will be negligible, however, since only a small fraction of the population (those escaping unemployment) benefits from increased income. The results reported in the above sections can thus be thought of as a sort of upper bound for the changes in inequality

38. For more details on potential growth and unemployment issues, see IMF (2010), which projects that growth for Panama will "hover around 6 percent, broadly in line with current potential growth."

39. This percentage (0.2 percent) is calculated as the percentage difference between the level of total employment achieved by the end of the construction phase (that is, by 2014) and the level of employment in the BaU scenario for the same year. It is thus equivalent to the cumulated (2004–14) employment effect.

and poverty. In an intermediate situation, where both wages and employment respond to the canal shock, employment effects would be even smaller and the wage effects would be somewhat muted, once again entailing reduced distributional impacts.[40]

There are also additional caveats to the results presented here, many of which indicate directions for future research. First, our estimates are based on a structural model and therefore are largely determined by the structure of the economy in the base year. Our expanded canal is essentially a larger version of the canal today; it does not develop any new linkages to the rest of the economy or generate important economywide spillovers (productivity or otherwise). Second, although we have attempted to link the macro- and microeconomic sides of the analysis as closely as possible, a number of inconsistencies remain. Our macroeconomic analysis does not capture self-consumption or intrahousehold transfers, which may be particularly important for the poorest households. Similarly, our microeconomic analysis does not take into account changes in payments to capital, which are relevant for the households in the top portion of the income distribution. Thus, our poverty and inequality results pertain mainly to the changes in returns to labor. Third, even if the unemployment rate in Panama is insensitive to periods of economic boom or bust, the response among underemployed workers may be significant. Our analysis may ignore potentially important employment creation effects through this channel. Finally, our microeconomic analysis focuses only on first-order effects and does not allow households to reoptimize their consumption bundle in response to aggregate price changes. Thus, we could be overstating the losses incurred by the poorest households, since they may be able to switch to lower-cost products when the prices of some food items rise.

Conclusions

The Panama Canal is a major source of export revenue for Panama, but its contribution to value added and employment is limited. Using a dynamic macro-micro framework, this paper has argued that the proposed expan-

40. Inequality is driven by changes in relative wages (skilled versus unskilled). In the additional CGE runs performed to test the robustness of the results, the skilled premiums increase less than in the standard (full employment) closure.

sion of the canal is likely to have significant macroeconomic effects only during the operations phase (2014 onward), and the income gains linked to the construction and operation of the new canal are likely to be concentrated in the top portion of the income distribution. There are three main reasons for these conclusions. First, our approach does not allow for any net employment creation from investment in the canal; this is consistent with econometric evidence on Panama's labor markets, but differs from the view adopted by several macroeconomic studies of the canal expansion. Second, Panama may experience sizable real exchange rate appreciation depending on the amounts of foreign borrowing during the construction phase and the larger revenues accruing from the expanded canal service exports during the operation phase. The additional inflows of foreign currency result not only in the loss of competitiveness of noncanal sectors (the Dutch disease effect), but also in higher domestic prices which hurt the poorest consumers in the Panamanian society even though the increase in nonfood CPI outpaces the rise in food CPI. Third, investment and operation of the expanded canal increase demand for formal workers in nonfarm activities, particularly those who have at least some secondary education. Although these changes encourage some additional movement of labor from agricultural to nonagricultural sectors and from informal to formal activities, much of the impact is manifested in growing wage disparities between the poor (agricultural workers, particularly indigenous groups) and the relatively well-off (skilled formal sector workers).

The results show that although aggregate poverty is likely to remain unchanged as a result of the canal project, income inequality and the poverty gap are likely to increase. To counteract these negative tendencies, the government could earmark some of the additional revenues of the Panama Canal Authority for funding a targeted cash transfer program. Results from an illustrative simulation show that, even allowing for imperfect targeting by allocating 5 percent of the revenues to administrative costs and another 20 percent to funds leakage, this policy action could reverse the adverse distributional impacts by almost eliminating extreme poverty and halving the moderate poverty headcount.

Appendix A: Economic Structure of Panama

TABLE A1. Sectors and Commodities in the Panama Social Accounting Matrix (SAM)

Production sector	*Formality*	*Associated commodities*
Canal	Formal	Canal and related services
Agriculture for domestic market	Formal	Maize, rice, oil seeds, swine livestock, poultry livestock, milk, and other domestic agricultural products
Agriculture for export market	Formal	Other livestock, fruits, fish products, shellfish, and other export agricultural products
Mining	Formal	Mining products
Manufacturing for domestic market	Formal and informal	Meat, dairy, grain products, and other domestic manufacturing
Manufacturing for export market	Formal and informal	Raw textile products, textiles, clothing, leather, and other export manufacturing
Electricity and water	Formal	Electricity and water
Construction	Formal and informal	Construction
Commerce and other services	Formal and informal	Commerce and other services
Transport communication	Formal and informal	Transport communication
Financial services	Formal	Financial services
Public administration	Formal	Public administration

TABLE A2. Economic Structure of Panama

Percent

						Value added			
Sector	*Contribution to output*	*Contribution to value added*	*Contribution to exports*	*Exports (% of output)*	*Imports (% of demand)*	Unskilled labor	Skilled labor	Formal capital	Informal capital
Canal	4.2	5.7	19.6	100.0		1	0		
Agriculture for domestic market	3.5	3.6	0.2	1.3	12.6	17	1	3	
Agriculture for export market	3.8	4.1	6.4	35.6	2.3	16	2	4	
Mining	1.0	1.0	0.7	13.7	51.8	0	0	2	
Manufacturing for domestic market	6.1	2.8	2.5	8.6	26.0	6	6	4	7
Informal	0.5	0.2				3	2		7
Formal	5.7	2.5				3	4	4	
Manufacturing for export market	12.4	11.2	30.9	53.4	63.4	2	1	18	38
Informal	1.6	1.1				2	0		38
Formal	10.8	10.1				0	0	18	
Electricity and water	2.4	2.9	0.0	0.1	5.2	0	1	5	
Construction	7.6	4.8				7	4	4	19
Informal	1.2	0.8				4	1		19
Formal	6.4	4.0				4	2	4	

Commerce and other services	11.1	9.2	0.9	1.8	0.0	35	34	5	28
Informal	2.4	2.3				24	12		28
Formal	8.7	6.9				11	23	5	
Transport & communications	8.9	9.2	22.2	53.4	12.8	5	7	9	8
Informal	1.1	1.4				4	3		8
Formal	7.7	7.8				2	5	9	
Financial services	26.1	28.3	16.7	13.6	3.4	3	11	41	
Public administration	12.9	17.3				8	33	5	
Total	**100.0**	**100.0**	**100.0**	**21.4**	**18.6**	**100.0**	**100.0**	**100.0**	**100.0**
Agriculture	7.3	7.7	6.6	19.3	8.5	33.1	3.5	7.0	0.0
Manufacturing	19.5	15.0	34.0	37.2	53.2	8.4	6.4	21.8	45.5
Services (incl. construction and canal)	73.2	77.3	59.4	17.3	4.9	58.3	89.9	69.5	54.5
Informal activities (excl. agriculture)	6.7	5.8				36.5	18.0	0.0	100.0
Formal activities	86.0	86.5				30.4	78.5	93.0	0.0

a. Authors' calculations, based on data from an updated 2003 social accounting matrix (SAM) for Panama and the Living Conditions Survey (*Encuesta de Niveles de Vida*, or ENV) databases for 1997 and 2003.

Appendix B: Identifying Labor and Capital Remunerations Using Household Survey Data

In household surveys, the primary source of income information, labor remunerations, and returns to capital are lumped together in the income figures reported by self-employed respondents. It is often important to distinguish the proportion of personal income that is accrued to the self-employed individual's labor inputs from what is attributable to capital. The objective of this note is to show how to identify the value added (VA) of capital using microeconomic data at the personal level.

We define the income of self-employed individuals as the sum of labor remunerations and returns to capital: $Y = Y^l + Y^k$. Assume that A and B are two randomly drawn individuals from the population who are identical in all characteristics except for their occupational category, where A is a wage worker and B is self-employed. Further assume that self-employment activities require an investment in physical capital greater than zero. Under competitive labor markets, B could earn a wage as high as the wage earned by A. Therefore, a good proxy for the unobserved value of Y^l for individual B is the expected wage given his or her personal characteristics. Under this simple setting, income gaps between A and B are attributable to returns to physical capital.

We define wages, w, as the sum of personal characteristics related to labor productivity, $\mathbf{X}$, valued at their market rate, β, plus a random component, ε:

$$\ln\left(w_i\right) = \alpha + \sum_j \beta_j \mathbf{X}_{i,j} + \varepsilon_i, \quad (1)$$

where $\varepsilon \sim N(0, \sigma^2)$ and $i \in$ (*earner*). The parameters in equation 1 can be used to estimate the expected value of the log of labor income for self-employed workers, if and only if the wage equation parameters apply to out-of-sample observations. A necessary condition to fulfill this requirement is that the partition between wage workers and the self-employed is the outcome of a random process. In other words, workers in the wage-earning sectors should be similar to self-employed workers once controlling for $\mathbf{X}_j$. If this condition is not met and wage workers are distinguished by certain unobservable characteristics that make them self-select into the wage-earning sectors, then β_j cannot be used to obtain an estimate of labor remunerations for the self-employed.

A simple modification to equation 1 can correct for the selection problem:[1]

(2) $$\ln(w_i) = \alpha^* + \sum_j \beta_j^* \mathbf{X}_{i,j} + \lambda \frac{\varphi(\mathbf{Z})}{\Phi(-\mathbf{Z}_i)} + \varepsilon_j^*,$$

where **Z** is a vector with the variables determining the probability of being a wage worker; φ(·) and Φ(·) represent the probability and cumulative normal distribution functions, respectively; and (α*, β*) are the parameters for the population regression model. Notice that vector **Z** contains all the personal characteristics **X** plus at least one extra variable (instrument) that is not related to wages but affects the probability of becoming a wage worker. Our hypothesis is that the decision of whether to be a wage worker or an earner is a result of the agent's risk aversion. Controlling for other personal characteristics, more risk-averse individuals will tend to choose the earnings sector as the preferred option. Savings can serve as a good proxy for risk aversion; risk-averse individuals would show higher savings rates than risk lovers. Therefore, higher saving rates, which proxy for higher risk aversion, should be positively related with the probability of being a wage worker. The population parameters (α*, β*) can be used to assign the expected value of earnings for self-employed workers:

(3) $$E\left[\ln\left(Y_g^l\right)\middle| X_g\right] = \hat{\alpha}^* + \sum_j \hat{\beta}_j^* \mathbf{X}_{g,j},$$

where $E[\cdot]$ is the expectations operator, $\hat{\alpha}^*$ and $\hat{\beta}^*$ are the population parameters estimated from equation 2, and $g \in$ (*self-employed*). To get the expected value of labor income in levels, Y^l,

(4) $$\hat{Y}_g^l = E\left[\left(Y_g^l\right)\middle| X_g\right] = \exp\left\{E\left[\left(Y_g^l\right)\middle| X_g\right]\right\} * \exp\left\{\sigma^2/2\right\},$$

where element $\exp\{\sigma^2/2\}$ is a scaling-up factor equal to $E[\exp\{\varepsilon^*\}] \Leftrightarrow \varepsilon \sim N(0, \sigma^2)$.[2] If $\hat{\alpha}^*$ and $\hat{\beta}^*$ are unbiased population parameters, $E[(Y_g^l - \hat{Y}_g^l)\,|\,X_g] = 0$ and it follows that

(5) $$\hat{Y}_g^k = Y_g - \hat{Y}_g^l.$$

1. Heckman (1979).
2. See Wooldridge (2003, p. 207). If ε does not follow a normal distribution, the scaling-up factor can be estimated by running a simple regression of *wi* on $\exp\{E[\ln(wi)]\}$ without an intercept and using the only estimated parameter as the correction factor.

Appendix C: Microeconomic Model Regression Results

TABLE C1. Mincer Equation Results for the Different Labor Market Segments[a]

		Nonagricultural sectors		
Explanatory variable	*Agricultural sectors*	*Total*	*Informal activities*	*Formal activities*
Urban	0.344	0.191	0.099	0.167
	(3.04)**	(5.55)**	(1.86)	(4.13)**
Household head	0.317	0.306	0.237	0.261
	(2.97)**	(9.10)**	(4.03)**	(7.17)**
Gender	0.193	0.237	0.187	0.123
	(0.95)	(7.64)**	(3.61)**	(3.54)**
Years of schooling	0.011	0.058	0.114	0.008
	(0.30)	(3.95)**	(4.65)**	(0.40)
Years of schooling squared	0.006	0.005	–0.001	0.005
	(2.61)**	(7.62)**	(0.53)	(6.66)**
Experience	0.088	0.080	0.085	0.066
	(8.98)**	(25.74)**	(17.33)**	(17.57)**
Experience squared	–0.001	–0.001	–0.001	–0.001
	(7.85)**	(18.91)**	(12.95)**	(12.02)**
Constant	5.113	5.078	4.624	6.179
	(19.32)**	(57.91)**	(36.65)**	(50.75)**
No. observations	997	6,907	2,793	4,114
Adjusted *R* squared	0.18	0.33	0.19	0.28

*Statistically significant at the 5 percent level.

**Statistically significant at the 1 percent level.

a. The dependent variable is log of labor income. Absolute value of *t* statistics in parentheses.

TABLE C2. Probit Estimation of the Probability of a Worker Changing Sector of Employment[a]

Explanatory variable	*Movement from agricultural to nonagricultural sectors*	*Movement from informal to formal activities*
Urban	−1.463	−0.324
	(309.49)**	(64.32)**
Household head	0.180	−0.359
	(31.54)**	(66.20)**
Gender	1.197	−0.689
	(186.35)**	(123.53)**
Years of schooling	−0.139	−0.041
	(147.78)**	(40.62)**
Experience	−0.012	−0.034
	(24.96)**	(64.00)**
Experience squared	0.000	0.001
	(23.66)**	(79.14)**
Household members	0.024	−0.006
	(32.35)**	(6.62)**
Self-employed	0.403	
	(89.11)**	
Other household members' income	0.000	
	(16.10)**	
Sectoral dummies	No	Yes
Constant	−0.354	1.830
	(29.53)**	(140.72)**
No. observations	5,762	3,201
Pseudo *R* squared	0.41	0.12

*Statistically significant at the 5 percent level.

**Statistically significant at the 1 percent level.

a. The dependent variable is equal to one if a worker has switched his or her sector of employment and zero otherwise. Absolute value of *z* statistics in parentheses.

Appendix D: Equations and Variables in the CGE Model

TABLE D1. Equations of the CGE Model

Variable	*Equation*
Demand for intermediate inputs bundle	$ND_i = \alpha_i^{nd} \left(\frac{PX_i}{PND_i} \right)^{\sigma_i^p} XP_i$
Demand for value added	$VA_i = \alpha_i^{va} \left(\frac{PX_i}{PVA_i} \right)^{\sigma_i^p} XP_i$
Output price	$PX_i = \left[\alpha_i^{nd} PND_i^{1-\sigma_i^p} + \alpha_i^{va} PVA_i^{1-\sigma_i^p} \right]^{1/(1-\sigma_i^p)}$
Producer price	$PP_i = \left(1 + \tau_i^p \right) PX_i$
Demand for intermediate inputs by good	$XA_{k,j} = a_{k,j} \left(\frac{PND_j}{PA_{k,j}} \right)^{\sigma_j^n} ND_j$
Price of intermediate goods bundle	$PND_j = \left[\sum_k a_{k,j} (PA_{k,j})^{1-\sigma_j^n} \right]^{1/(1-\sigma_j^n)}$
Demand for unskilled labor bundle	$UL_i = \alpha_i^u \left(\frac{PVA_i}{PUL_i} \right)^{\sigma_i^{kl}} VA_i$
Demand for capital/skilled labor bundle	$KSK_i = \alpha_i^{ksk} \left(\frac{PVA_i}{PKSK_i} \right)^{\sigma_i^{kl}} VA_i$
Price of value added	$PVA_i = \left[\alpha_i^u PUL_i^{1-\sigma_i^{kl}} + \alpha_i^{ksk} PKSK_i^{1-\sigma_i^{kl}} \right]^{1/(1-\sigma_i^{kl})}$
Demand for skilled labor bundle	$SKL_i = \alpha_i^s \left(\frac{PKSK_i}{PSKL_i} \right)^{\sigma_i^{ks}} KSK_i$
Demand for capital	$K_i^d = \alpha_i^k \left(\lambda_i^k \right)^{\sigma_i^k - 1} \left(\frac{PKSK_i}{R_i} \right)^{\sigma_i^k} KSK_i$
Price of capital/skilled labor bundle	$PKSK_i = \left[\alpha_i^s PSKL_i^{1-\sigma_i^{ks}} + \alpha_i^k \left(\frac{R_i}{\lambda_i^k} \right)^{1-\sigma_i^k} \right]^{1/(1-\sigma_i^{ks})}$
Demand for unskilled labor by type	$L_{i,ul}^d = \alpha_{i,ul}^l \left(\lambda_{i,ul}^l \right)^{\sigma_i^u - 1} \left(\frac{PUL_i}{W_{i,ul}} \right)^{\sigma_i^u} UL_i$
Demand for skilled labor by type	$L_{i,sl}^d = \alpha_{i,sl}^l \left(\lambda_{i,sl}^l \right)^{\sigma_i^s - 1} \left(\frac{PSKL_i}{W_{i,sl}} \right)^{\sigma_i^s} SKL_i$
Price of unskilled labor bundle	$PUL_i = \left[\sum_{ul \in \{\text{Unskilled labor}\}} \alpha_{i,ul}^l \left(\frac{W_{i,ul}}{\lambda_{i,ul}^l} \right)^{1-\sigma_i^u} \right]^{1/(1-\sigma_i^u)}$

TABLE D1. Equations of the CGE Model *(Continued)*

Variable	*Equation*
Price of skilled labor bundle	$PSKL_i = \left[\sum_{sl \in \{\text{Skilled labor}\}} \alpha^l_{i,sl} \left(\frac{W_{i,sl}}{\lambda^l_{i,sl}} \right)^{1-\sigma^s_i} \right]^{1/(1-\sigma^s_i)}$
Labor income	$LY_l = \sum_i NW_{i,l} L^d_{i,l} + ER.FW_l$
Capital income	$KY = \sum_i NR_i K^d_i$
Profits	$Prof^c_e = \left(1 - \kappa^c_e\right)\left(KY + ER.TR_{W,e} + r^g_d GDebt\right)$
Corporate saving	$S^c_e = s^c_e Prof^c_e$
Corporate transfers to households	$TR^H_{c,e} = Prof^c_e - S^c_e$
Household disposable income	$YD_h = \left(1 - \lambda^h \kappa^h_h\right) \left(\underbrace{\sum_l \varphi^h_{l,h} LY_l}_{\text{Labor}} + \underbrace{\sum_e \varphi^h_{e,h} TR^H_{c,e}}_{\text{Enterprise}} + \underbrace{PLEV.TR^H_{g,h}}_{\text{Transfers from government}} + \underbrace{ER.TR^h_{W,h}}_{\text{Foreign remittances}} \right)$
Household consumption	$XA_{k,h} = Pop_h \theta_{k,h} + \frac{\mu_{k,h}}{PAc_{k,h}} \left((1 - s^h_h) YD_h - \sum_{k'} PAc_{k',h} Pop_h \theta_{k',h} \right)$
Household saving	$S^h_h = YD_h - \sum_k PAc_{k,h} XA_{k,h}$
Household consumer price index	$CPI_h = \frac{\sum_k PAc_{k,h} XA_{k,h,0}}{\sum_k PAc_{k,h,0} XA_{k,h,0}}$
Consumer price	$PAc_{k,h} = PA_{k,h}(1 + \tau^c_{k,h})$
Nonhousehold final demand	$XA_{k,f} = \alpha^f_{k,f} \left(\frac{PF_f}{PA_{k,f}} \right)^{\sigma^f_f} XF_f$
Nonhousehold final demand price	$PF_f = \left[\sum_k \alpha^f_{k,f} \left(PA_{k,f} \right)^{1-\sigma^f_f} \right]^{1/(1-\sigma^f_f)}$
Value of final demand	$YF_f = PF_f XF_f$
Demand for domestically produced goods	$XD^d_{k,a} = \alpha^d_{k,a} \left(\frac{PA_{k,a}}{PD_k \ (1 + \tau^{cd}_{k,a})} \right)^{\sigma^m_{k,a}} XA_{k,a}$
Demand for foreign-produced goods	$XMT_{k,a} = \alpha^m_{k,a} \left(\frac{PA_{k,a}}{(1 + \tau^{cm}_{k,a}) PMT_{k,a}} \right)^{\sigma^m_{k,a}} XA_{k,a}$
Armington price	$PA_{k,a} = \left[\alpha^d_k \left(PD_k \ (1 + \tau^{cd}_{k,a}) \right)^{1-\sigma^m_{k,a}} + \alpha^m_k \left((1 + \tau^{cm}_{k,a}) \ PMT_{k,a} \right)^{1-\sigma^m_{k,a}} \right]^{1/(1-\sigma^m_{k,a})}$
Import price (domestic currency)	$PM_{k,r} = ER.WPM_{k,r}$

(*continued*)

TABLE D1. Equations of the CGE Model *(Continued)*

Variable	*Equation*
Import demand	$XM_{k,r} = \alpha^{w}_{k,r}\left(\frac{PMT_{k,a}}{PM_{k,r}}\right)^{\sigma^{w}_{tr,k}} \sum_{a} XMT_{k,a}$
Export price (domestic currency)	$PE_{k,r}\,(1+\tau^{e}_{k,r}) = ER.WPE_{k,r}$
Supply of home produced goods for domestic market	$XD^{s}_{k} = \gamma^{d}_{k}\left(\frac{PD_{k}}{P_{k}}\right)^{\sigma^{x}_{k}} X_{k}$
Supply of home produced goods for exports	$XET_{k} = \gamma^{e}_{k}\left(\frac{PET_{k}}{P_{k}}\right)^{\sigma^{x}_{k}} X_{k}$
Output price	$P_{k} = \left[\gamma^{d}_{k} PD_{k}^{1+\sigma^{x}_{k}} + \gamma^{e}_{k} PET_{k}^{1+\sigma^{x}_{k}}\right]^{1/(1+\sigma^{x}_{k})}$
Export volume	$XE_{k,r} = \gamma^{x}_{k,r}\left(\frac{PE_{k,r}}{PET_{k}}\right)^{\sigma^{z}_{k}} XET_{k}$
Export price	$PET_{k} = \left[\sum_{r}\gamma^{x}_{k,r} PE_{k,r}^{1+\sigma^{z}_{k}}\right]^{1/(1+\sigma^{z}_{k})}$
Export demand	$\begin{cases} ED_{k,r} = \alpha^{e}_{k,r}\left(\frac{\overline{WPE}_{k,r}}{WPE_{k,r}}\right)^{\eta^{e}_{k,r}} (1+g^{w}_{r})^{\eta^{w}_{k,r}} & \text{if} \quad \eta^{e}_{k,r} \neq \infty \\ WPE_{k,r} = \overline{WPE}_{k,r} & \text{if} \quad \eta^{e}_{k,r} = \infty \end{cases}$
Equilibrium conditions	$X_{k} = \sum_{i\in K} XP_{i,}$, $P_{k} = \sum_{i\in K} PP_{i,}$, $\sum_{a} XD^{d}_{k,a} = XD^{s}_{k}$, and $ED_{k,r} = XE_{k,r}$
Government income	$GY = \underbrace{\sum_{k}\sum_{a}\tau^{cd}_{k,a}(PD_{k} + PTMG_{k}\tau^{mg,D}_{k,a})\,XD^{d}_{k,a}}_{\text{Sales tax on demand for domestic goods}} + \underbrace{\sum_{k}\sum_{a}\tau^{cm}_{k,a} PMT_{k,a} XMT_{k,a}}_{\text{Sales tax on demand for import goods}}$ $+ \underbrace{\sum_{l}\sum_{i}(\tau^{xfl}_{i,l} + \tau^{sfl}_{i,l})\,NW_{i,l}L^{d}_{i,l}}_{\text{Wage tax and subsidies}} + \underbrace{\sum_{e}\kappa^{c}_{e} CY_{e}}_{\text{Corporate tax}} + \underbrace{\lambda^{h}\sum_{h}\kappa^{h}_{h} YH_{h}}_{\text{Income tax}} + \underbrace{ER.TR^{g}_{W}}_{\text{Transfers from ROW}}$ $+ \underbrace{\sum_{i}\tau^{p}_{i} PX_{i} XP_{i}}_{\text{Production tax}} + \underbrace{ER.\sum_{md}\sum_{k}\sum_{r}\tau^{m}_{k,r,md} WPM_{k,r} XM_{k,r}}_{\text{Import distortions}}$
Government expenditure	$GEXP = YF_{Govnt} + PLEV\sum_{h} TR^{H}_{g,h} + ER.TR^{W}_{g} + r^{g}_{d}\,Debt^{g}_{d} + r^{g}_{f}\,Debt^{g}_{f}.ER$
Government saving	$S^{g} = GY - GEXP$
Savings-investment balance	$YF_{Invst} + YF_{Ginvst} = \sum_{e} S^{c}_{e} + \sum_{h} S^{h}_{h} + S^{g} + ER.BOR^{g}_{f} + ER.S^{p}_{f} + ER.FDI$
Volume of gov. consumption	$XF_{Govnt} = \alpha_{Govnt}(RGDPMP)^{\eta^{g}}$
Volume of gov. investment	$XF_{GInvst} = \alpha_{GInvst}(RGDPMP)^{\eta^{zg}}$
Armington price index	$PLEV = \frac{\sum_{a}\sum_{k} PA_{k,a} XA_{k,a,0}}{\sum_{a}\sum_{k} PA_{k,a,0} XA_{k,a,0}}$

TABLE D1. Equations of the CGE Model *(Continued)*

Variable	*Equation*
Rural labor supply	$L^s_{l,Rur} = (1+g^L_{l,Rur})\,L^s_{l,Rur,-1} - MIGR_l$
Urban labor supply	$L^s_{l,Urb} = (1+g^L_{l,Urb})\,L^s_{l,Urb,-1} + MIGR_l$
Total labor supply	$L^s_{l,Tot} = \sum_{gs} L^s_{l,gs}$
Rural-urban wages	$AWAGE_{l,gz} = (1-UE_{l,gz})\dfrac{\sum_{i\in gz} NW_{i,l}L^d_{i,l}}{\sum_{i\in gz} L^d_{i,l}}$
Rural-urban migration	$MIGR_l = \chi_l^{migr}\left(\dfrac{AWAGE_{l,Urb}}{AWAGE_{l,Rur}}\right)^{\omega_l^m}$ if $\omega_l^m \neq \infty$
Wage by sector	$NW_{i,l} = \phi^l_{i,l} W^e_{i,gz}$ for $i \in gz$
Post-tax wage by sector	$W_{i,l} = (1+\tau^{xfl}_{i,l} + \tau^{sfl}_{i,l})\,NW_{i,l}$
Capital supply by sector	$K_i^s = \gamma_i^k\left(\dfrac{NR_i}{PK}\right)^{\omega^k} TK^s$
Price of capital	$PK = \left[\sum_i \gamma_i^k NR_i^{1+\omega^k}\right]^{1/(1+\omega^k)}$
Capital equilibrium condition	$K_i^s = K_i^d$
Foreign saving	$S_f = S_f^g + S_f^p$
Government domestic borrowing	$BOR_d^g = \chi_g\left(YF_{ginvst} - S_g\right)$ $BOR_d^g = \sum_e S_e^c$
Government saving-investment	$YF_{Ginvst} = S^g + BOR_d^g + ER.BOR_f^g$
Debt dynamics	$Debt_d^g = Debt_{d,-1}^g + BOR_d^g$ $Debt_f^g = Debt_{f,-1}^g + BOR_f^g$ $Debt_f^p = Debt_{f,-1}^p + S_f^p$ $Debt^g = Debt_d^g + ER.Debt_f^g$
GDP at current prices	$GDPMP = \sum_k\sum_h PAc_{k,h}XA_{k,h} + \sum_k\left[PA_{Invst}XA_{Invst} + PA_{Ginvst}XA_{Ginvst}\right] + \sum_k PA_{Govnt}XA_{Govnt} + ER\sum_k\sum_r\left(WPE_{k,r}XE_{k,r} - WPM_{k,r}XM_{k,r}\right)$
GDP at base year prices	$RGDPMP = \sum_k\sum_h PAc_{0,k,h}XA_{k,h} + \sum_k\left[PA_{0,Invst}XA_{Invst} + PA_{0,Ginvst}XA_{Ginvst}\right] + \sum_k PA_{0,Govnt}XA_{Govnt} + ER_0\sum_k\sum_r\left(WPE_{0,k,r}XE_{k,r} - WPM_{0,k,r}XM_{k,r}\right)$
GDP deflator	$PGDPMP = GDPGMP/RGDPMP$
GDP at factor cost	$GDPFC = \sum_l\sum_i W_{i,l}L^d_{i,l} + \sum_k\sum_i R_iK_i^d$
GDP growth	$RGDPMP = (1+g^y)\,RGDPMP_{-1}$
Productivity	$\lambda^l_{ip,l} = (1+\gamma^l + \chi^l_{ip,l})\,\lambda^l_{ip,l,-1}$
Capital stock growth	$TK^s = TK^s_{-1} + XF_{Invst}$

TABLE D2. Indices Used in the Model

Index	Definition
i	Production activities
k	Commodities
l	Labor skills
ul	Unskilled labor[a]
sl	Skilled labor[a]
kt	Capital types
lt	Land types
e	Corporations
gz	Geographic zones (rural, urban, national)
h	Households
f	Final demand accounts[b]
a	Armington agents[c]
r	Trading partners

a. The unskilled and skilled labor indices, *ul* and *sl*, are subsets of *l*, and their union composes the set indexed by *l*.
b. The standard final demand accounts are government current and capital expenditures and private investment.
c. The index *a* is the union of production activities, *i*, households, *h*, and other final demand accounts, *f*.

TABLE D3. Endogenous Variables

Variable	Definition
Production variables	
ND_i	Demand for aggregate intermediate demand bundle
VA_i	Demand for value added bundle
PX_i	Producer price net of production tax
PP_i	Producer price
$XA_{k,j}$	Intermediate demand for goods and services
PND_i	Price of aggregate intermediate demand bundle
KL_i	Demand for capital-labor bundle
ND_i^d	Demand for sector-specific resource
PVA_i	Price of value added bundle
UL_i	Demand for aggregate unskilled labor bundle
KSK_i	Demand for capital/skilled labor bundle
PKL_i	Price of capital-labor bundle
SKL_i	Demand for aggregate unskilled labor bundle
KT_i^d	Demand for aggregate capital bundle
$PKSK_i$	Price of capital/skilled labor bundle
$LV_{i,l}^d$	Sectoral variable demand for labor by labor type
PUL_i	Price of aggregate unskilled labor bundle
$PSKL_i$	Price of aggregate skilled labor bundle
$L_{i,l}^d$	Sectoral total demand for labor by labor type
PKT_i	Price of aggregate capital demand bundle
$K_{i,kt}^d$	Sectoral total demand for capital by capital type
XP_i	Aggregate output from activity *i*
Income distribution variables	
LY_l	Aggregate net labor remuneration
KY_{kt}	Aggregate after-tax capital income

TABLE D3. Endogenous Variables *(Continued)*

Variable	*Definition*
$TR^{E}_{k,kt}$	Capital income transferred to enterprises
CY_{e}	Corporate income
S^{c}_{e}	Corporate retained earnings
$TR^{h}_{c,e}$	Corporate earnings transferred to households
YD_{h}	Disposable income net of taxes and transfers
TR^{H}_{h}	Aggregate transfers by households
TR^{W}_{h}	Household transfers abroad
Domestic demand variables	
$XA_{k,h}$	Household demand for goods and services
S^{h}_{h}	Household savings
CPI_{h}	Household-specific consumer price index
$PAc_{k,h}$	Consumer prices
$XAf_{k,f}$	Other domestic final demand for goods and services
PF_{f}	Other domestic final demand price deflator
YF_{f}	Other domestic final demand aggregate expenditure level
Trade variables	
$XD^{d}_{k,a}$	Domestic demand for domestic production
$XMT_{k,a}$	Domestic demand for aggregate imports
$PA_{k,a}$	Price of Armington good
$PM_{tr,k,r}$	Domestic tariff-inclusive price of imports by region of origin
$XM_{tr,k,r}$	Import demand by region of origin and tariff regime
$PMT_{k,a}$	Price of imports by Armington agent
$PE_{k,r}$	Producer price of exports by region of destination
XD^{s}_{k}	Domestic output sold domestically
XET_{k}	Aggregate export supply
X_{k}	Aggregate output
$XE_{k,r}$	Export supply by region of destination
PET_{k}	Price of aggregate exports
$ED_{k,r}$	Demand for exports by region of destination
Goods price equilibrium variables	
PD_{k}	Price of domestic goods sold domestically
$WPE_{k,r}$	World price of exports by region of destination
Macroeconomic variables	
GY	Government revenues
$GEXP$	Total government current expenditures
S^{g}	Nominal government savings
λ^{h}	Household direct tax schedule shifter
XF_{Invst}	Volume of private investment
$PLEV$	Absorption price deflator
$CPIT$	Aggregate consumer price deflator
$GDPMP$	Nominal GDP at market price
$RGDPMP$	Real GDP at market price
$PGDPMP$	GDP at market price deflator
$GDPFC$	Nominal GDP at factor cost
$RGDPFC$	Real GDP at factor cost
$PGDPFC$	GDP at factor cost deflator

(*continued*)

TABLE D3. Endogenous Variables *(Continued)*

Variable	*Definition*
Factor market variables	
$L^s_{l,gz}$	Labor supply
$AWAGE_{l,gz}$	Expected average wage rate
$MIGR_l$	Rural to urban migration
$WMIN_{l,gz}$	Minimum wage
$W^e_{l,gz}$	Equilibrium wage rate
$NW_{i,l}$	Sector-specific wage rate net of wage tax
$W_{i,l}$	Sector-specific wage rate
TK^s_{kt}	Aggregate capital supply by type
PK	Economywide aggregate rate of return to capital
$K^s_{i,kt}$	Sectoral capital supply by type
PTK_{kt}	Economywide aggregate rate of return to capital by type
$NR_{i,kt}$	Sectoral rate of return to capital by type net of tax
$R_{i,kt}$	Sectoral rate of return to capital by type
Growth variables	
g^y	Growth rate of real GDP
$\lambda^l_{ip,l}$	Sector- and labor-specific growth factor

TABLE D4. Exogenous Variables

Variable	*Definition*
Growth factors	
γ^{l}	Economywide labor productivity growth
$\lambda^{k}_{i,kt}$	Capital productivity factor
$\lambda^{t}_{i,lt}$	Land productivity factor
λ^{nr}_{i}	Sector-specific factor productivity
K^{s}	Aggregate (normalized) capital stock
$LAND$	Aggregate land supply
Trade prices	
$WPM_{k,r}$	World price of imports (CIF)
$\overline{WPE}_{k,r}$	Export price index of competitors
ER	Exchange rate and model numéraire
Fiscal variables	
XF_{Govnt}	Volume of government expenditures on goods and services
τ^{p}_{i}	Production tax
$\tau^{cd}_{k,a}$	Sales tax on domestic goods
$\tau^{cm}_{k,j}$	Sales tax on import goods
$\tau^{c}_{k,h}$	Subsidies on household consumption
κ^{h}_{h}	Initial marginal direct tax rates
$TR^{h}_{g,h}$	Transfers from government to households
κ^{c}_{e}	Corporate tax rates
χ_{md}	Uniform tariff adjustment factor
$\tau^{m}_{tr,k,r,md}$	Sectoral tariffs by region of origin and tariff regime
$\tau^{e}_{k,r}$	Sectoral export taxes by region of destination
$\tau^{xfl}_{i,l}$	Wage tax by sector and labor type
$\tau^{xfk}_{i,kt}$	Capital tax by sector and capital type
$\tau^{sfl}_{i,l}$	Wage subsidy by sector and labor type
$\tau s^{sfk}_{i,kt}$	Capital subsidy by sector and capital type

Comment

Francisco H. G. Ferreira: When major infrastructure investments are large enough to have general equilibrium effects, how can their impacts on poverty or the distribution of incomes be assessed? What about the effects of substantial increases in a country's ability to extract rents from its natural resources? Is it possible that such gains might worsen the welfare of the very poor, even while contributing to increases in aggregate national income? Bussolo, de Hoyos, and Medvedev investigate the distributional effects of the Panama Canal expansion—a large infrastructure project that enhances Panama's ability to extract rents from its geographical position—to shed new light on these questions.

The expansion of the Panama Canal represents a massive infrastructure investment, estimated to cost approximately 40 percent of Panama's 2003 GDP, over a seven-year horizon. Such a large investment could arguably be expected to have multiplier effects on output and employment across the entire country. In addition, both by attracting large inflows of dollar-denominated loans during the construction phase and by raising canal revenues during the subsequent operation phase, it might affect the country's real exchange rate and, hence, relative domestic prices. Both of these channels could mediate the effects of the canal expansion on poverty and inequality, through the general equilibrium of the economy.

The existence of such general equilibrium effects poses serious problems for most approaches normally used to evaluate the distributional impact of infrastructure interventions. One might, a priori, consider estimating the impact of the canal expansion by comparing changes in outcomes for households located near the Canal Zone with those living farther away, using propensity score matching techniques analogous to those used by Escobal and Ponce to evaluate the effects of rehabilitating rural roads in Peru.[1] Alternatively, if a suitable instrument were found, one might adopt

1. Escobal and Ponce (2002).

an instrumental variables (IV) strategy such as that employed by Duflo and Pande to evaluate the impact of irrigation dams on district-level poverty in India.[2] However, if relative prices are changing across the entire economy, and if multiplier effects are affecting labor demand even in far-flung areas of the country, then instruments are unlikely to be valid, and comparison groups are almost certainly contaminated.

The strategy adopted in this paper is to tackle the general equilibrium effects head-on, by means of a macro-micro model that combines a computable general equilibrium (CGE) model with a household-survey-based microsimulation module. Additional expenditures and borrowing associated with ex ante plans for the canal expansion are fed into a CGE built for Panama and are allowed to affect investment, output, labor demand, and so on, relative to a baseline ("business-as-usual") scenario. The model ultimately predicts certain changes in equilibrium prices, wages, and labor allocation, which are fed down to earnings and occupational choice equations estimated on household survey data. Those equations allow the authors to simulate changes in wages and employment patterns at the level of individuals and households, in a manner consistent both with the preexisting conditional distributions observed in the microeconomic data and with aggregate changes predicted by the general equilibrium model.

My main methodological comment is that the failure to contrast model predictions with ex post historical data represents something of a missed opportunity for this paper. As the authors acknowledge, and as appendix D makes abundantly clear, the use of a CGE combined with a microsimulation model necessarily implies reliance on a large number of assumptions. "Identification of impact," even with all the caveats about scenarios, rather than forecasts, is obviously conditional on all of these assumptions. The justification for embarking on such an exercise is, as noted above, that the intervention in question will plausibly have significant general equilibrium effects, so that alternative techniques would lead to confounded estimates. Even so, such an assumption-heavy technique calls for as much validation by real data as possible.

The paper relies on a social accounting matrix (which underpins the CGE) and a household survey, both from 2003. It also uses population and GDP growth forecasts taken at some (not precisely specified) point in the last decade. When simulating the canal expansion scenario, for comparison with the business-as-usual benchmark, it relies on an ex ante plan of expenditures for the 2007–14 period. We are now in 2012, and much of the relevant

2. Duflo and Pande (2007).

macroeconomic data exist for Panama until 2011. Household survey data exist at least for 2008 (in the form of the *Encuesta de Niveles de Vida—ENV 2008*) and possibly for later years. It is difficult to imagine that some of these data could not have been used to shed light on the performance of the model for the business-as-usual scenario between 2003 and 2008 and, for the macroeconomic module, until more recently. If the baseline scenario had been simulated for 2003–11, for example, and compared with real data, one would certainly learn a lot about how reliable the 2003–14 estimates are likely to be. To be clear: the suggestion would not have been to recalibrate the model using more recent time-series data, but to assess the performance of the dynamic computable general equilibrium model, calibrated on a previous period, on a fresh time sample not used for calibration. Similarly, the ENV 2008 household data might have been used to compare actual poverty and inequality statistics for that year with a simulation run for 2003–08. The performance of such an exercise would be enormously informative for how confident one might be of the simulation results presented for 2014 and 2020. In general terms, if the growing macro-micro simulation literature wants to be taken seriously, despite its heavy reliance on all sorts of assumptions, it has to face the data.[3]

Abstracting for a moment from the above caveat, what can policymakers from Panama learn from this paper? First, despite a modest contribution to faster economic growth (mostly in the operation phase, after 2014), there is a real risk that the canal expansion may have a regressive effect on the income distribution. The model-predicted effect on poverty is small, both in the construction phase (2003–14) and in the operational phase (2014–20). In the latter period, a small decline in the poverty headcount coexists with an increase in the depth of poverty, driven by increasing inequality. Welfare losses are concentrated among the rural poor who do not migrate from rural to urban areas or, more accurately, who do not diversify away from agriculture into nonagricultural activities. The losses are driven by rising domestic prices, rather than by falling nominal incomes. Most of the income gains from the canal expansion are concentrated in the top half of the income distribution, among those in the formal nonagricultural sector, where both employment and wages expand. Even though most of the direct increases in labor demand

3. Ferreira and others (2008) is one of the few papers that compares simulation results from a macro-micro model with actual ex post data. In this study of an exchange rate devaluation in Brazil, model performance was found to be uneven (p. 160).

are in the construction sector, canal construction is relatively skill intensive, and the skill premium is simulated to rise as a result of the expansion.

From the viewpoint of poverty reduction, these results suggest little hope that the benefits of the large investments and rising exports associated with the Panama Canal expansion will trickle down to the poorer segments of society. In line with the common characterization of the canal as an enclave, with relatively few employment linkages with the rest of the economy, it seems that whatever multiplier effects the expansion might engender are likely to be confined to the higher-skill segments of the labor force. In addition, because of the effects on exchange rate and price levels, the expansion might well end up raising the cost of living of those poor people who do not benefit from it in any way. Although the margins of error around these scenarios are likely to be large, given all of the assumptions that underpin them, the broad contours that arise from the exercise seem plausible enough. It is then difficult to disagree with the authors that if the Panamanian government is at all concerned with poverty reduction, it ought to seriously consider setting aside some, if not all, of the extra public revenues likely to be generated by the expanded canal for targeted transfers to its poorest citizens. Even if perfect targeting is difficult, it seems clear that some of the most vulnerable, including indigenous people living in rural areas, would not see any benefit from the canal expansion unless it were through this channel of public redistribution.

That is an important lesson from thinking about the general equilibrium effects of this large infrastructure investment and its distributional consequences. If the government takes heed and plans the redistribution in advance, the paper will already have made a contribution. Greater confidence on specific results, however, would require validation of some of the simulation exercises against ex post data.

References

Armington, Paul S. 1969. "A Theory of Demand for Products Distinguished by Place of Production." Staff Paper 16. Washington: International Monetary Fund.

Bourguignon, François, Maurizio Bussolo, and Luiz A. Pereira da Silva, eds. 2008. *The Impact of Macroeconomic Policies on Poverty and Income Distribution: Macro-Micro Evaluation Techniques and Tools.* Washington: World Bank.

Bourguignon, François, and Luiz A. Pereira da Silva, eds. 2003. *The Impact of Economic Policies on Poverty and Income Distribution: Evaluation Techniques and Tools.* Washington: World Bank.

Bussolo, Maurizio, and others. 2008. "Trade Options for Latin America: A Poverty Assessment Using Macro-Micro Linkages." In *The Impact of Macroeconomic Policies on Poverty and Income Distribution: Macro-Micro Evaluation Techniques and Tools,* edited by François Bourguignon, Maurizio Bussolo, and Luiz A. Pereira da Silva. Washington: World Bank.

Chen, Shaohua, and Martin Ravallion. 2004. "Welfare Impacts of China's Accession to the World Trade Organization." *World Bank Economic Review* 18(1): 29–57.

Deaton, Angus, and John Muellbauer. 1980. *Economics and Consumer Behavior.* Cambridge University Press.

Duflo, Esther, and Rohini Pande. 2007. "Dams." *Quarterly Journal of Economics* 122(2): 601–46.

Escobal, Javier, and Carmen Ponce. 2002. "The Benefits of Rural Roads: Enhancing Income Opportunities for the Rural Poor." Working Paper 40. Lima: Grupo de Análisis para el Desarrollo (GRADE).

Ferreira, Francisco H. G., and Phillippe G. Leite. 2003. "Meeting the Millennium Development Goals in Brazil: Can Microeconomic Simulations Help?" *Economía* 3(2): 235–79.

Ferreira, Francisco, and others. 2008. "Can the Distributional Impacts of Macroeconomic Shocks Be Predicted? A Comparison of Top-down Macro-Micro Models with Historical Data for Brazil." In *The Impact of Macroeconomic Policies on Poverty and Income Distribution,* edited by François Bourguignon, Maurizio Bussolo, and Luiz A. Pereira da Silva, chap. 5. Washington: World Bank.

Galiani, Sebastián. 2006. "El mercado de trabajo en Panamá: notas para su análisis." Washington University in Saint Louis.

Heckman, James. 1979. "Sample Selection Bias as a Specification Error." *Econometrica* 47(1): 153–61.

IMF (International Monetary Fund). 2007. "Panama: Staff Report for the 2006 Article IV Consultation." Washington.

———. 2010. "Panama: 2010 Article IV Consultation—Staff Report." Washington.

Lokshin, Michael, and Ruslan Yemtsov. 2005. "Has Rural Infrastructure Rehabilitation in Georgia Helped the Poor?" *World Bank Economic Review* 19(2): 311–33.

Panama Canal Authority. 2006a. “Plan Maestro del Canal de Panamá.” Panama City. Available online at www.pancanal.com/esp/plan/documentos/plan/acp-plan-maestro.pdf.

———. 2006b. “Proposal for the Expansion of the Panama Canal: Third Set of Locks Project.” Panama City. Available online at www.pancanal.com/eng/plan/documentos/propuesta/acp-expansion-proposal.pdf.

Ravallion, Martin, and Shaohua Chen. 2003. “Measuring Pro-Poor Growth.” *Economics Letters* 78(1): 93–99.

Ravallion, Martin, Shaohua Chen, and Prem Sangraula. 2007. “New Evidence on the Urbanization of Global Poverty.” Policy Research Working Paper 4199. Washington: World Bank.

Servén, Luis, and César Calderón. 2004. “The Effects of Infrastructure Development on Growth and Income.” Working Paper 3400. Washington: World Bank.

Stone, Richard. 1954. “Linear Expenditure System and Demand Analysis: An Application to the British Pattern of Demand.” *Economic Journal* 64(255).

Székely Miguel, and Marianne Hilgert. 1999. “What’s behind the Inequality We Measure: An Investigation Using Latin American Data.” Working Paper 409. Washington: Inter-American Development Bank.

Van der Mensbrugghe, Dominique. 2005a. “Instructions for Running the Prototype CGE Model: A User’s Manual for the Tunisia CGE Model.” Technical report. World Bank.

———. 2005b. “Prototype Model for a Single Country: Real Computable General Equilibrium Model.” Technical report. World Bank.

Wooldridge, Jeffrey. 2003. *Introductory Econometrics: A Modern Approach,* 2d ed. Mason, Ohio: South-Western Cengage Learning.