Employment impact assessments: A review of methodologies

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List of abbreviations

CGE	Computable general equilibrium
CPI	Consumer price index
EIIP	Employment-Intensive Investment Programme (ILO)
GDP	Gross domestic product
I-O	Input-output
ILO	International Labour Organization
LCU	Local currency unit
LDC	Least developed country
PIP	Public investment project
PSBR	Public sector borrowing requirement
RCT	Randomized controlled trial
SAM	Social accounting matrix
US$	United States dollar

Abstract

This paper reviews methodologies for the ILO's Employment Assessment project. While many other excellent sources have participated in this effort, this paper takes the viewtack that employment assessment is something that local governments can take on themselves. It therefore provides a primer on how the first steps towards an independent analytical capability might be taken. To this end, both micro and macro approaches are considered, from project monitoring and evaluation to input-output analysis and computable general equilibrium models, both static and dynamic. The focus throughout is the subtle interplay between structure and data. The goal is to offer to practitioners of public sector investment projects some initial tools for evaluation of the employment impact of these projects.

Keywords: Employment, Impact Assessment, Randomized Controlled Trials, Input-Output, Social Accounting Matrices, Computable General Equilibrium Models, Agent-based Models.

1. Introduction

The path to full employment with decent working conditions has been long and tortuous. Most of the individuals and their families who have escaped the grind of poverty in the last 400 years have done so without the help of aid or international organizations (Clemens et al., 2012). Still, help in the "Great Escape"–the title of a recent book from the latest Nobel Prize laureate–from external sources in the the latter part of the 20th century has not been insignificant, especially with respect to public health (MacAskill, 2015). The purpose of this study is to help sharpen the effort that can be made by the ILO in precisely this regard. How can technical experts, sitting in offices, possibly help poor countries employ more of their own people? This paper introduces the simple well-known analytical methodologies that may be of use in shaping more effective interventions.

At the abstract level, the linkages are clear: there must be growth in demand for goods and services that broadly matches the availability of workers and their levels of skill and education. Workers who have escaped poverty have done so by combining their efforts with capital equipment and structures in a way that their marginal product meets or exceeds the total cost of employment. Since the industrial revolution, wages have been sufficient to elevate consumption levels, whilst employment has generated sufficient profit for further capital accumulation.

These general principles are widely recognized, not the least by the European Commission (EC) and the International Labour Organization (ILO). Their shared goal is to ensure that economic growth and integration with global markets result in productive employment, decent work and poverty reduction, because these outcomes are not automatic. Rather, success requires policy interventions grounded in appropriate methodologies derived from careful attention to economic theory as well as empirical evidence. A useful set of analytical tools would identify possibilities for areas where intervention can kick-start processes to increase availability of employment and decent work.

The specific purpose of this study is to provide a primer for the methods usefully summarized in a variety of ILO technical reports. This paper does not seek to recapitulate these studies but instead to offer assistance to field economists who must implement the recommendations of those studies.[1]

The goals of the study are to

- describe existing analytical methods, and combinations of methods which can be used for employment impact assessment.
- review various studies to document results obtained by different methods used.
- Distinguish between methods sensitive to the goals of the ILO regarding both *quantity* and *quality* of employment.
- describe the scope, data and computational resources needed, noting strengths and weaknesses of the approach.

The paper is organized as follows: section 2 discusses programme-level monitoring and evaluation. Section 3 introduces input-output methods and Social Accounting Matrices (SAMs) as their generalization. Section 4 addresses the development of computable general equilibrium (CGE) Models. Section 5 considers dynamic SAMs and associated CGEs while section 6 looks ahead to other simulation methods. A final section concludes.

2. Programme-level monitoring and evaluation

The five major reasons identified by Flyvbjerg (2014)) to undertake public investment projects might be to:

1. create and sustain employment.
2. improve balance of payments if project replaces imports.
3. improve productivity and competitiveness by lowering production costs.
4. benefit consumers through higher-quality services and benefits producers by providing cheaper and better intermediates.

[1]Specifically, the ILO is conducting activities in at least 10 EC partner countries located in different regions. The focus is on developing countries in Africa, Arab States, Asia, Central and South America, and the Commonwealth of Independent States (CIS). The countries in which employment impact assessments will be conducted are Côte d'Ivoire, Ethiopia, Ghana, Guatemala, Honduras and Rwanda. See UNCTAD (2015) for specific public investment projects and sectoral policies in the least developed economies (LDCS). The report notes for instance that Rwanda, Africa's most densely populated country, did not have the road density of India in 1950. India's road density today is 32 times that of Ethiopia and 255 times that of Sudan (UNCTAD, 2015, p. 61). Rwanda has not yet arrived at demographic transition and population pressures on agricultural land are severe. The hectares to worker ratio was 0.8 in 1980 and fell to 0.4 in 2012, just behind Bangladesh at 0.28 and Nepal at 0.36. For reference, the average ratio in LDCs was 3.3 in 2012 (UNCTAD, 2015, p. 74).

5. augment environmental amenities when new, clean infrastructure replaces old.

It should be noted from the outset that in standard cost-benefit analysis, labour enters as a *cost* rather than a benefit (Gruber, 2011; Mishan and Quah, 2007). Cost-benefit analysis is widely used to evaluate public programmes and projects. It rests on a number of assumptions that non-economists often question and sometimes with great vigor. Since it is based almost entirely on fundamental economic principles, no economist has successfully proposed a workable, general-purpose alternative.

To fix ideas here is a list of the key components of the approach:

- *Opportunity costs* are the only true costs. Only costs associated with diverting a given resource from its next best use are considered. Accounting costs, used by governments to sum the input costs of a given project, are not proper measures of opportunity costs. Measurement of opportunity costs presents significant challenges, but this in itself is not a reason to embrace the accounting cost alternative.
- *Rents* are not part the of the costs of diverting a resource from its next best use and should not be counted in the sum of opportunity costs.
- Only if worker are efficiently employed can the labour cost of their wages be used as their opportunity cost. "Efficiency" here means that workers are paid no more than is required to pull them away from their next best employment opportunity. In other words, there are no rents incorporated into the wage. Thus, the idea that labour cost is measured by the wage is true whether workers are employed formally, informally or in subsistence agriculture. Indeed, in the latter two categories it is much *less* likely that the wage rate would be distorted by a rent, caused by trade unions, government procurement contracts or other non-competitive processes.
- If workers are unemployed, their labour is measured by the value of their *leisure*.
- Future costs are discounted to present values by way of the standard discounting expression. While there can be debate on the proper discount rate to use in this exercise, this debate is healthy and properly constrained by the cost-benefit approach.
- If there are significant externalities, a *social rate of discount* that differs from the private rate can be used.
- Benefits include cost of time saved, statistical cost of saved lives and other goods and services that can be produced as result of the proposed projects.
- labour or job creation is not properly considered a benefit of a project but any increase in the level of economic activity that results from the presence of the project is.
- Uncertainty in cost-benefit analysis is an area of contention. For example, no generally agreed upon method of evaluating the future impact of climate change, for example, exists.
- Once a cost-benefit analysis is coded, it can be stress tested to see how the project stands up to a wide variety of plausible scenarios, without having to agree on their relative likelihood. This agree-on-the-final-decision approach avoids the tedious, contentious

and irresolvable disputes that arise when policy-makers must agree on assumptions (Kalra et al., 2015, p. 26).

2.1. Monitoring and evaluation

Cost-benefit analysis is used to determine whether a public investment project (PIP) is acceptable in the sense that its direct and indirect costs do not exceed its direct benefits plus net positive externalities.[2] Once a PIP has been selected and is underway, analysts can use various methods to gauge the employment impact of public investment and sectoral policies. In order to determine the ex-ante direct employment effects of PIPs, it is first necessary to determine the size and scope of the project, the path of the labour demand by skill category and overhead employment costs. These are dynamic variables inasmuch as they typically vary over the course of the project.

Labour demand functions are traditionally determined by the marginal productivity of the worker as determined by the firm's production function. On the PIP demand side, this is given by the nature of the project and productive processes involved. The supply side is more complex, with the flow of labour from the informal/subsistence sector dependent on the opportunity cost, what is given up, when the worker leaves their next best alternative–whether a formal, informal or subsistence job–and joins the labour force of the PIP. While there is no reason for governments to pay more than the opportunity cost of the PIP, it is quite likely that they do, mixing a labour rent in with the opportunity cost. This rent must be deducted from the cost of labour to arrive at an accurate measure of the opportunity cost of labour.[3]

An implicit assumption in some of the monitoring literature is that the opportunity cost of the projects being monitored is effectively zero. Comparison across projects that could be done with the resources is the only way to determine a project's desirability (Taylor and Lybbert, 2015). Donor evaluation–as distinct from cost-benefit analysis–may include other criteria. The choice of project, for example, might include not just the number or quality of jobs produced, but the net job creation.[4] If jobs are simply moved from one sector to another, the employment impact is zero. Without taking these interactions into account, resources are likely to be wasted. Monitoring, therefore, should include indicators of such intersectoral shifts. This is, in some cases, explicitly included in the goals of the project. For example, Ernst and Sarabia (2015) note that preservation of existing jobs is a necessary goal of the Egyptian stimulus package that they evaluated. More generally, whatever methodology is applied, as Irrek et al. (2007) discuss, all impacts, direct and indirect, must be considered before any one project can be said to be the most effective in employment creation.

[2] Ernst et al. (2015) list a number of examples of PIPs: water supply, reforestation, erosion control, small dam construction, irrigation, watershed management, feeder road construction, rehabilitation and maintenance, schools, health centers, cereal banks, slum upgrading, street paving, sanitation and drainage.

[3] In the traditional Lewis model, the wage in the formal sector is equal to the opportunity cost in the informal or subsistence sector (Lewis, 1954). In the Harris-Todaro framework, the wage does involve a rent since formal sector employers wish to pay more than the opportunity cost of labour to ensure that there is a labour queue or to identify the most motivated or capable workers (Harris and Todaro, 1970).

[4] Breitschopf et al. (2011) present a useful summary of assessment methods according to whether they account for only gross or can estimate *net* job creation in the renewable energy sector.

One difficult issue is incorporation of social impact into monitoring and evaluation exercises. The usual goal of this approach is to assess the distributional impact of PIPs, since a common result in impact assessments is that the poorest receive limited benefits (Schweikert and Chinowsky, 2013; Hettige, 2006). Several indices have been constructed to help with this very task and typically include benefits such as improved health, education and access to information as well as the amount of vulnerable employment, precarious work and informal employment resulting from a PIP (Hettige, 2006; Ernst et al., 2015; Schweikert and Chinowsky, 2013). However, when extended to account for social effects of a PIP, one is no longer using cost-benefit analysis, but is rather monitoring or evaluating the project from the donor perspective. For example, de Vet et al. (2010) discuss the conceptual and empirical difficulties, even for European Union (EU) countries, in measuring the redistributive impact of policies on social indicators, such as social inclusion and protection, public health and safety, and labour standards.

Given the difficulty of "clean identification" (specifying, measuring and connecting the investment to the social outcome), it may be that this approach should be used sparingly. As Lombard and Coetzer (2007) suggest: "Since measuring social benefits is difficult, this only needs to be done if a transport cost savings and time savings approach does not provide enough justification in terms of the economic rate of return [ERR] estimates. In most cases, the ERR estimates for rural low volumes roads will not be able to justify investments." This quotation illustrates the dangers of arguing in reverse from conclusions to premises to satisfy donor objectives.

A counterargument calls for the use of cost-benefit analysis specifically designed for projects in the poorest areas on the grounds that conventional cost-benefit methods might undercount or miss entirely significant benefits for the level of development of an area. In other words, a "bridge to nowhere" may in fact become a bridge to somewhere, simply because building the bridge makes a wide range of future investment projects profitable, even though these projects are not yet on the drawing board. This point has not been lost on the Chinese government.

Distributional goals illustrate the same point a bit differently. Since no individual benefits from a better distribution of income unless their income is higher, distributional benefits are not properly included in cost-benefit analysis. This is not true from the donor perspective, however, if redistribution is a goal of the project. The problem is that, for a project to be successful, it must promote economic activity, but economic activity is more likely to be generated in an area already more developed. Thus, the distributional consequences of PIPs may be negative (Grootaert, 2002). To this end, the World Bank has developed the Roads Economic Development (RED) model specifically for low volume roads, which using conventional cost-benefit analysis would not be funded.

2.2. Distributional concerns

PIPs are often criticized on distributional grounds. Following on with the example of road projects, Hettige (2006) notes that

> Roads are clearly a critical enabling condition for improving living conditions in rural areas. However, the distribution of socioeconomic benefits resulting from a rural road is a separate issue, and there are no guarantees or inherent mechanisms to ensure that these benefits will be distributed equitably between the poor and the non-poor in communities.

Evaluation that includes distributional goals is more likely to conclude that a project is worthwhile than conventional cost-benefit analysis. Note, however, that this way of targeting a particular population or region can be wasteful of resources if the opportunity costs are not calculated carefully. It may well be the case that another project with a lower cost-benefit ratio measured conventionally still has spill-over effects on the poor that exceed the specifically pro-poor project. This is especially true for infrastructure and long-lived projects.

As will become evident in this assessment, the issue is far from clear-cut. First of all, models need to be fine-grained to pick up reliable distributive effects. While they can compute Lorenz curves and Gini coefficients, these may relate to the underlying structure of the model itself rather than the data. Moreover, growth is arguably inherently unequal: "bacteria will not grow in a petri dish in a way that would "ensure that the benefits will be distributed equitably..." Roads that serve only the rich and not the poor seem terribly inequitable, but may give rise to investment that increases dramatically the demand for unskilled labour.

Ernst et al. (2015) usefully distinguish *monitoring* and ex post *evaluation* of projects. Monitoring collects data on performance criteria during the execution of the project and provides data for subsequent evaluation. Monitoring is an aspect of project management and is concerned with coordination, bottlenecks, critical paths and material supply chains. Monitoring is unconcerned with the employment generating aspect of PIPs and effective monitoring and project management may well *reduce* labour costs. Compliance with environmental and labour codes are part of monitoring but may have little to do with whether the project actually delivers its expected benefits.

Efforts to confound project monitoring with evaluation are therefore not helpful. A project specification that includes a requirement to create a given number of jobs for targeted beneficiaries may impede the successful completion, on-time and on-budget, of the project itself and thereby put future projects, whether complementary or not, at risk. Interdisciplinary Research Consultants (2014) notes

> Several contractors noted that there is a general lack of skilled labour in the market. While there are some conditions that require contractors to hire Jordanians, those conditions are not correlated with job categories, and rather apply to the overall hires. Also, hiring labour from areas far from the project's vicinity remains . . . cumbersome. This is mainly due to the need to provide housing and transportation for such labour.

Any bias expressed against "non-local" or immigrant labour has no place in effective PIP monitoring and evaluation. Policy-makers may adopt this view, but they cannot use economic theory to support their position. Discriminating against immigrant labour leads to an inefficient allocation of resources, most visible in the case of the labour market, and this is virtually non-negotiable in standard economic theory. Immigrant labour enhances competition, increases employment of labour per unit of capital and stimulates the accumulation of human capital, all positive outcomes for any country.

The lack of skilled workers is simply an expression of a shortage of human capital, a shortage that must be remedied by expanded educational opportunities or other training. Banerjee and Duflo (2012) point out that for this to come about, there needs to be a persistent demand for skilled labour, something PIPs with their somewhat sporadic nature cannot always provide. One reason that the People's Republic of China has been so successful is that, typically, PIPs are layered in a sequence that supports a lasting incentive to accumulate human capital.

The skill mix of demand for labour resulting from PIPs is to some extent controversial. If the PIP builds demand for the upper echelon workers, the effect on poverty indices will be attenuated compared to the same spending on their low-income counterparts. Some have argued that an imbalanced approach to skilled/unskilled labour market stimulus can be counterproductive if a shortage of employment opportunities for skilled labour results in their competing in the unskilled labour market, out-competing the unskilled for the low-wage work that the latter would have otherwise received (Skott and Auerbach, 2003).

Employing locals who are not needed for project completion, but who satisfy some quota or distributional requirements, is inefficient. It also paves the way for rent seeking, corruption and loss of public support. Large projects may involve or necessitate technical audits, quality assessment and control and engineering second opinions. If these were done by an objective, outside agency, the value of the audit would increase.

Evaluation can be undertaken ex ante or ex post and involves larger goals than project management. An employment assessment involves an analysis of the impact on local labour markets, both on factor demand *and* factor supply. While monitoring does not imply evaluation, evaluation may involve monitoring and management methods, especially if cost overruns have occurred. It follows from the discussion above that evaluation is primarily concerned with the cost-benefit ratio. . If the analysis has been undertaken carefully and competently, this is, in principle, all that is required for evaluation.

In practice, however, many projects are undertaken for which the cost-benefit analysis yields a ratio greater than one. Policy-makers may and often do decide to adopt a project that does not meet cost-benefit analysis specifications. As noted above, this often happens when distributional goals are included in the project specification. Moreover, low-balling cost estimates can be part of a political strategy to get initial project approval. Problems that arise later can be dealt with by Hirschman's "hidden-hand", an appeal to human creativity in confronting unanticipated engineering, regulatory and/or economic obstacles to project completion. If the cost-benefit ratio has exceeded one since its inception, it may well be worthwhile evaluating the project's *cost-effectiveness.* Could the same objectives have been met at a lower cost, even if the project as a whole was not worthwhile? The latter may be due to significant uncertainty in the evaluation of benefits, their magnitude and the scope of beneficiary participation. A project that greatly enhances inclusiveness, for example, may well involve benefits that are vague and thus difficult to quantify, as noted above.

2.3. Measuring jobs: quantity and quality

It is worth bearing in mind that while the supply of labour in LDCs is complex, the demand side is much more straightforward. Strictly speaking, if a PIP pulls workers from other sources of employment, whether formal, informal or subsistence, no new "jobs" are created. Jobs are only created when workers are pulled from leisure. The value of leisure to workers is not zero, but if they are employed in any fashion whatsoever, it is less than the income generated.

If someone leaves the farm to work on the PIP and an unemployed sibling does the farm work, a chain of employment can be visualized. Only if the last link of the chain attracts some individual somewhere from leisure can it be said that a new job has been created. If no one is willing to make this trade-off and leisure remains constant, a PIP causes unemployment in some sector that had previously been occupied. The rise in well-being as the worker moves to the PIP is then partially offset by the loss in gains from trade previously enjoyed as the last link in the employment chain is vacated. Observe, however, that the PIP must result in an unambiguous increase in well-being since it was the worker's choice to leave the job on the farm. Strictly speaking, the loss in welfare of frustrated consumers of farm produce cannot be compared with the gain the worker experiences in leaving, but it is often seen by policy-makers as a win-win situation when it is really win-lose.

It is thus useful to see labour in developing countries as fully employed, always doing something, either formally or informally. Leisure may have significant value in developed countries, but the income elasticity of the demand for leisure is typically considered to be relatively high. This implies that workers in low-income countries show a stronger preference for income compared to workers in developed countries. Oddly, full employment is thus more relevant to developing rather than developed countries, so long as "employment" is not limited to formal sector jobs.

The assumption of "full employment" may seem stringent but it allows a distinction between the *quantity* of jobs and the *quality* of jobs. Just as it may be concluded that if an idle worker moves into an informal sector job, the value of the income is higher than the value of leisure, it must also be true that if a worker leaves an informal job for a formal one, the *quality* of the latter is higher even if the wage is the same. The advantages of this economic perspective are numerous: first, the worker defines the job quality rather than some outside observer Second, the observation that a worker has moved from one job to another is objective evidence of improved job quality. The difficulty of judging job quality is that the dimensions of quality vary across workers. This is not to say that all jobs are high quality just because workers accept them. It is rather that measuring job quality is complex. While a part-time job may, for one worker, constitute underemployment and thus low quality, to another worker the availability of less than full time work may be highly desirable.

PIPs often pay higher than market wages. If so, workers' opportunity cost rises and private sector employers may well be discouraged from employing them. On the other hand, the higher wage provides an incentive to leave their second-best alternative, whether a job in the formal, informal/subsistence sector or leisure activities supported by transfers from family, the church, or, in some cases, a government-provided social safety net.

A proposed definition of "employment" offered by the Resolution of the 19th International Conference of Labour Statistics bolsters the idea that complex decision making on the supply side is simplified by the offer of formal sector employment on the demand side (Organization, 2013). Any given individual may be engaged in a range of activities that might include part-time formal work, informal, own-use production, for subsistence or not, or voluntary work. This is entirely consistent with the notion of opportunity cost: individuals assign subjective weights to all these activities, high or low, and then aggregate. On the basis of this aggregate, they choose, or not, to join a PIP labour force. If they do, then we say they are better off because of the first axiom of revealed preference. In less technical terms, while no new jobs have necessarily been created, social well-being is higher.

Macroeconomic models are uniquely qualified to address questions such as "if wages increase for certain individuals, what happens to the rest?" A rise in wages or an increase in hours and better shop-floor conditions, certainly convey the impression that better jobs have been be created. An improvement in any of these metrics would ceteris paribus improve welfare unambiguously. Macroeconomic models challenge the notion of "qualitatively better jobs" by forcing a level of accounting consistency on estimates. When ceteris is not paribus, a qualitative improvement in one sector of the economy may lead to a decline in well-being elsewhere. For a *generalized* rise in the quality of employment, it may well be the case that a macroeconomic indicator such as total investment over GDP might have to rise. For this to happen, wages may need to be lower, not higher. The model thus imposes macro (rather than micro) foundations on claims that job quality can improve autonomously. Policy-makers must be aware of the macroeconomic constraints if unintended (and unwanted) consequences are to be avoided.[5]

The first step in computing an employment impact on the economy is to convert the labour demand to a number of *full-time equivalent jobs* or equivalent annual employment (EAE). This computation is not as straightforward as it might seem when contracts are staggered and last for less than one year. Let $l_{ij} \leq 1$ be length of the contract, measured in days, for the ith worker in skill category j. This enables the framework to account for informal, temporary or sub-contracting (job-shopping) labour. Employment in skill class j, E_j, or EAE is then given by

$$E_j = \frac{\sum_i^n w_{ij} l_{ij} H_j (1 + \omega_{ij})}{W_j} \tag{1}$$

where there are n contracts at wage rate w_{ij} contracted for H_j hours per year. Here ω_{ij} is the indirect or overhead cost per wage unit and W_j is the average yearly compensation for a full-time employee in the jth skill rank.[6]

Serious principal-agent problems can arise when incentives are mismatched. It may be in the interest of the government as far as its donors or taxpayers are concerned to *overstate*

[5] This is not to put macroeconomic models on a pedestal. Clearly they are only as valid as the underlying data, which is necessarily gathered at the micro level. In sum, the micro or partial equilibrium analysis must be complemented by the macroeconomic perspective and vice versa.

[6] This is a discrete approximation to a continuous function, of course, and can be rescaled for a shorter horizon than the year for which the accounting is done here.

the employment effect of the PIP by over reporting the contract length l_{ij}, thereby inflating the number of workers employed during the course of the year. Interdisciplinary Research Consultants (2014) recommends direct field verification of employment, by explicit examination of the concordance between site visits and site records. The problem raised by many observers, Easterly (2003) most vocal among them, is the alignment of incentives between donor and government that blocks any real evaluation of costs and benefits of the PIP. A coalition can arise between contractors and government in which government overpays for labour services it never receives, an arrangement secured by lack of counter-party surveillance on behalf of the tax-paying public. Lack of competition can lead to cost-plus contracts and subsequent cost overruns and change-order manipulation by which contractors manage to extract rents from the public sector. Careful monitoring by trained and experienced personnel, perhaps by the ILO itself, can reduce costs, but may inflict some political damage on the PIP. "Trust but verify" is a clear directive here, but when it comes to quality, durability and long-term value-for-money, additional challenges are faced.

The reluctance to undertake thorough ex post project evaluation is one of the most clearly identified problems with PIPs and seems to scale with the size of the project. Flyvbjerg (2014) finds that for rail projects studied, there is an average cost overrun of 44.7 per cent, combined with an average demand (benefit) *shortfall* of 51.4 per cent. For roads, there is an average cost overrun of 20.4 per cent combined with a 50 per cent risk that demand is also incorrect by more than 20 per cent.

Ernst et al. (2015) makes the case most succinctly for employment impact assessments: "...in the case of all the methodologies...running from the straightforward to the complex, the vision is simple: remember to count!" and one would add: "remember to count objectively and accurately."

2.4. Public and private goods

The authors are reminding policy-makers to assess the employment impact of PIPs as a "reality check" on the *net* job creating potential of a given project. Politicians, trade-unions, activists and the voting public often see "job creation" as the job of the public sector. As noted, however, there is no foundation in economic theory for this view. The conventional role of the public sector is to augment the provision of *public goods* (goods that are non-rival and non-excludable) and therefore will be under-produced by the private sector. Job creation is the province, at least in traditional economic theory, of the private sector.

A helpful biological analogy suggests that organs in the body must be connected by way of bone structure, circulation and the nervous system. Organs are modular, specific to their task and highly specialized, while connective tissue is more general purpose, serving the needs of modularity by establishing a closed network. It is not difficult to see the analogy here: on the one hand, connections are goods that are public in nature and will be under-provided by the private sector. On the other hand, the degree of evolution, specialization and internal architecture of organs, requires full-time attention to their development and is not easily given to command and control. Above all, modularity is excludable and rival simply disconnect the organ from the network and its services are no longer available.

Roads, and other infrastructure, are clearly the most general examples of connective tissue and are thus quintessentially public goods. However, to be effective they must connect something. Howe (2001) makes the point, not unrelated to the discussion of distributional equity above:

> First a positive response could only be expected in areas in which a "prior dynamism" existed. If a particular region is growing rapidly in terms of population, output, and so forth, the probability is very great that existing transport facilities will soon constitute a true bottleneck even if there is some excess capacity at the moment. The existence of overall dynamism implies, inter alia, an environment in which economic opportunity tends to be sought and quickly exploited when found. By definition this is not normally a characteristic associated with areas in which poverty is prevalent on a significant scale.

Public goods may either be provided either publicly or by way of private provision.[7] Private goods are subject to competitive forces from domestic and foreign sources and it is incumbent on firms to select a technique that maximizes profits. Foreign direct investment may well result in a combination of highly capital-intensive methods with extremely cheap labour by developed country standards. There is nothing counter-intuitive about firms using capital-intensive methods when local labour is in excess supply. These firms must compete internationally with firms who benefit from extensive and reliable infrastructure and who are collocated with the markets they serve.

None of these competitive forces applies to PIPs in developing countries. Competition for infrastructure projects, for example, does not rise to the pitched level observed in clothing or automobiles. This opens up a space for the ILO to promote labour-intensive production of PIPs and other public goods, even when private sector production processes are vastly more capital-intensive as a result of the competition they perceive. The ILO's Employment-Intensive Investment Programme (EIIP) of the ILO seeks to raise the labour-intensity of public sector projects. It can only really apply to public goods for which the competitive mechanism is suspended by non-excludability.

The immediate effect of raising the opportunity of cost of labour in public works projects is to put *downward* pressure on the profitability of private sector firms, reducing exports and discouraging further direct private investment. However, there are two mitigating factors at work here. The first is that private firms frequently offer a wage premium to ensure proper queuing of the most productive local labour. Raising the opportunity cost of labour will have less of an effect on firms who are already paying relatively high wages. The second is that improved infrastructure will partially offset any rise in labour costs that the PIP provokes (Ernst and Sarabia, 2015).

There is more to this story, however. Consider a rise in the wage rate brought about by a PIP. This may cause workers who were content with part-time employment to now begin looking for for full-time jobs in the formal sector. Analytically, the labour force has *increased* by

[7] See Gow (2014) on the relative merits of public versus private provision, especially with regard to innovation. However, further exploration of this topic is beyond the scope of this survey.

these new entrants. This would apply *downward pressure* to the observed wage rate, further mitigating the loss of export competitiveness or incentive to invest.

Ernst et al. (2015) make the case that evaluation can itself serve as a stimulus to wider acceptance of PIPs. The most celebrated example of this is *Progresa/Oportunidades* in Mexico, initiated by the Zedillo administration in 1997, and evaluated by way of a randomized controlled trial (RCT). The improvement in health and educational outcomes in the treatment arm were so significant compared to the control group, the subsequent Fox administration was almost forced to continue the programme, changing its name to *Oportunidades* in 2001 (Fernald et al., 2008). Transparency and third-party verification of the randomized evidence was crucial in the decision to continue the programme (Ayres, 2008).

Green jobs are less clear cut (Jarvis et al., 2011). In some limited context, it might be satisfactory to note simply that green jobs are ipso facto inefficient since had they offered higher well-being they would already exist in proper proportion. However, this view ignores environmental externalities, which may be significant in the cases of some countries. Global public goods aside, misallocation of domestic resources can lead to societal cavitation and collapse, as in the case of the deforestation of the island of Hispanola, as documented by Diamond and many others (Diamond, 2005).

In any case, green jobs may have limited impact and they may not even be green when direct and indirect inputs are taken into account. Alarcón et al. (2005) find that for Indonesia, the green jobs both raise productivity and require higher skill levels. With all else equal, raising productivity will have a negative effect on employment, so for green jobs to be employment-enhancing they must have an impact on demand that is greater than the increase in productivity. Indeed, the Indonesian results show a higher growth of employment overall for brown (non-green) jobs (Alarcón et al., 2005, p.14).

2.5. The *randomistas*

There are two broad approaches in social sciences and each has pushed its paradigm to new heights recently. On the one hand there are the *post-modernists* who claim that truth is elusive, subjective and defined by the user. Economic theory soundly rejects this approach and, in recent years, has developed a closer affinity to empirical methods in the physical sciences including experimentation on live subjects and, above all RCTs Banerjee and Duflo (2012) summarize the use of RCTs in development economics and this approach can be usefully applied to the kind of public investment projects discussed here. Grootaert (2002) discusses the use of RCTs in evaluating road projects, noting that economists must often rely on natural experiments since they are cheaper, obviously feasible and less likely to run afoul of ethical or legal constraints. On the other hand, a vigorous literature critical of the use of RCTs has emerged, most notably in the work of Deaton.

The criticisms of the RCT approach amount to ensuring that the randomization is actually random and not correlated with the effect the treatment is supposed to bring about. A second criticism is that while the two arms (subsets) of the studied sample will not, indeed cannot, be identical, there may be systematic differences that are in fact correlated with the treatment. RCTs also suffer from the problem of the dichotomy of internal/external validity. A well-designed clinical trial that shows treatment effectiveness in Los Angeles need not apply to Johannesburg. These are significant criticisms, but they seem to fall short of ruling out the RCT mechanism as so defective that it cannot be added to the empirical arsenal.

The Abdul Latif Jameel Poverty Action Lab (JPAL) at the Massachusetts Institute of Technology, (MIT), Cambridge, MA, in the United States, (MIT) is at the centre of the development of the use of RCTs in economics with the goal of finding effective policies to reduce poverty. Its justification for this approach to impact assessment is "Randomized evaluations are often deemed the gold standard of impact evaluation, because they consistently produce the most accurate results …to determine whether a programme has an impact, and more specifically, to quantify how large that impact is."

Experimental design in RCTs must deal with two core issues. The first is the need for *baseline surveys*. These are costly, but necessary for determining the initial conditions against which the impact of a programme will be measured (Kasy, 2015). The second is *selection bias*, which can be difficult to eradicate. This arises when the location or population segment receiving the treatment, investment for a PIP, for example, may be unlike locations and populations in the control arm. If after the investment, the treatment group experiences a rise in income, employment or some other social indicator, selection bias may reduce the likelihood that the treatment alone *caused* the improvement. The key to understanding this is to note that the differences in outcomes *must be correlated with the treatment itself*. If not, the baseline survey can uncover many sources of variation that are utterly irrelevant to the validity of the method.

With respect to PIP projects, as noted above, it may be that more developed areas are more likely to compete for and receive investment funds than poor areas (Grootaert, 2002). Therefore, higher incomes post-project may be due to the investment or simply to the initial higher level of development. First differences would eliminate this problem, but there can be latent variables at play. The hope of the *randomistas* is that these variables are distributed in the *entire sample* in a way that no sub-sample differs from any other by more than *two standard deviations*.

In a public health setting, selection bias arises when the location or population given the treatment would have been better off without the treatment. Impact assessment then demands that the effect of the treatment and the effect of the underlying differences between those receiving and those not receiving the treatment be separated out. Without controlling for selection bias, the impact of a project will be overstated.[8]

[8]The opposite can happen in the face of spill-over effects from a project such as infrastructure. A local project may have a positive impact on other areas or populations outside of the project area because incomes, for example, rise from the higher consumption of the affected populations. Without taking these secondary effects into account, the impact of a project will be understated. Note further that control is precisely what regressions try to do when looking for a causal relationship between a dependent and an independent variable. Is the control complete? Obviously not due to the random error present in the sample. If the random error is large enough, there is no reason to control for the correlated effect and this is *precisely what a baseline study ensures*. Hence RCTs require no controls whatsoever.

2.5.1. Coping with selection bias

More formally, the total observed impact of a project can be separated into two parts, the "true" impact of the treatment and the impact of the selection bias. This exercise requires some suspension of disbelief, in that the selection bias component requires a hypothetical counterfactual that is logically impossible. It does show quite clearly, however, the exact way in which selection bias affects the results of impact assessment.

Following Taylor and Lybbert (2015), consider a case in which each individual i has an outcome with treatment of Y_{1i} and without treatment of Y_{0i}. If selection bias is not present, the treated and the untreated populations are *statistically identical* in the sense that there are no statistically significant differences between them apart from the treatment. If so, the impact of the treatment would be the difference in the average outcomes between all treated and all untreated individuals. With selection bias, those who were treated might have had better outcomes even without treatment and the differences in averages do not accurately measure the treatment effect. To measure selection bias, it is necessary to calculate another difference, that between the outcome of the treated population when treated and the outcome if the treated population had not been treated. This last construct is the counterfactual that could never happen; the treated cannot be untreated, hence the warning to suspend disbelief.

To identify the selection bias, it is convenient to define a variable D_i that has a value of 1 if the ith individual is treated and a value of 0 if not. Thus

$$Y_i = Y_{1i} \;\; if \;\; D_i = 1$$

and

$$Y_i = Y_{0i} \;\; if \;\; D_i = 0$$

The average expected outcome with treatment is

$$E[Y_i|D_i = 1]$$

and without is

$$E[Y_i|D_i = 0]$$

Selection bias is then

$$E[Y_{0i}|D_i = 1] - E[Y_{0i}|D_i = 0]$$

because the first term is the expected outcome of those who did get treated, if they had not been treated and the second term is the expected outcome of those who did not get treated. This accounts for differences in the populations treated and untreated, because it compares outcomes without treatment. If the outcomes without treatment are significantly different, the populations are not sufficiently similar to rule out selection bias. To measure the impact of the treatment, rather than the differences in populations before treatment, the bias as defined above would have to be subtracted from the total impact the treatment is found to have. Since the treated people cannot be untreated, how can this be addressed? The whole point of RCTs is to choose populations similar enough that bias is minimized or eliminated, therefore driving the bias component to zero and leaving only the "true" effect as is observed.

Although increasingly seen to be the best methodology for impact assessment, RCTs have limitations in that they cannot by themselves explain the mechanisms behind the impact. While, if properly conducted, they are very good at determining cleanly the impact, they are not designed to ask why or how the impact happened. Kasy (2015) also suggests that conditional independence only requires a controlled trial and not an RCT, using the covariates from the baseline survey to assign treatments statistically rather than randomly. This approach obviously requires highly reliable and detailed baseline data. Moreover, no new data are created.

2.6. Cost of employment creation

While Ernst et al. (2015) appropriately emphasize that jobs must, above all, be counted, the evaluation process cannot stop there. In order to make a decision about future policy on the basis of a completed PIP, a *number* must be assigned to each job created showing how much it cost to create it. A job that cost US$100,000 to create but only pays $20,000 cannot be justified no matter how badly the job is needed. As noted above, economists conventionally hold that jobs are not in themselves valuable; it is the demand for goods and services that arise from a job that confers utility. So long as labour is devoted to the production of goods and services that has a valuation greater than its costs, it is clear that job creation signals higher levels of well-being. Conversely, jobs that are created in the process of diverting resources to uses that have little or no demand cannot be justified (except perhaps as countercyclical expansionary monetary and fiscal policy). For this, cost-benefit analysis is indispensable and any attempt to abandon that method for some less well-specified alternative will become counterproductive.

To understand the employment impact of a project, it is necessary to take into account the issues raised above, including cost-benefit analysis, opportunity costs and unintended consequences of targeting specific segments of the labour force or population. Without a cost-benefit analysis of possible projects, the loss of resources involved in choosing a project solely because of its direct employment effects is unrecognized. Similarly, not taking into account the opportunity costs assesses a project in isolation from alternatives that could be more efficient in using resources, and thus be more capable of job creation over time. Finally, ignoring the consequences of targeting specific groups can be counterproductive, as demonstrated by the example of unemployed skilled workers crowding out unskilled workers when employment growth focuses on the low-skill category.

3. Input-Output methods and Social Accounting Matrices

Jobs are created as a result of an increase in the project's demand for materials and services attributable to the PIP. If these goods and services come from existing inventories, then no new jobs are created. Only when those inventories are replaced do so-called "backward linkages" come into play, as desired inventory/sales ratios are restored. The replacement requires capital and labour, and if the PIP does not crowd out other sources of demand, there is a rise in the demand for labour. In the short run, the labour intensity of production processes increases; in the longer term, there must be new savings, new investment and net accumulation of capital stocks in the PIP. This will stimulate other domestic sources of supply that produce intermediate goods for the PIP.

In the poorest of countries, this process may not quite unfold this way. Poor countries lack backward linkages, especially for PIPs, and may have to resort to imports. In the halcyon days of fixed exchange rates, this may well have provoked a balance of payments crisis. In the modern era, however, a depreciation of the local currency unit (LCU) is much more likely and if the adjustment is not too extreme, exports sectors will become somewhat more competitive. Thus, the backward linkages are still, to some extent, present.

It is important not to lose sight of the role of PIPs at a more basic level. It is indeed odd to be discussing crowding out when the entire purpose of a PIP is to “crowd in” private sector investment. While some crowding out may become perceptible in the post-project data stream, the employment effects of a well-designed PIP can scarcely be expected to be negative.[9]

Thus, assume for the moment that no demand is crowded out by the investment project. To maintain inventories, the producer must expand output and in the process hire new workers. Once paid, these workers will arrive at other locations–in the domestic economy or abroad–and demand goods and services. The result is that the inventory loss will reappear at the destination. A new cycle, with new workers, will begin and this could, potentially, go on forever, with an arbitrarily large rise in output and employment spurred on by the initial fall in inventories.

In the real world, employment does not spiral in this way, principally because the loss in inventories at the second location is slightly smaller than at the first under the assumption that marginal propensity to consume is less than one, that is, the workers save some of their income.

At each stage of production some intermediate goods, raw materials and other inputs, are required. These are similar to capital goods, but in fact only last a fraction of the period of production while capital goods last longer than one period. Let X_j be the output of one of n sectors in a given period. A simple average cost function would be

$$p_j X_j = \sum_{i}^{n} p_i a_{ij} X_j + \sum_{l=1}^{m} w_{lj} l_{lj} + r_j k_j \tag{2}$$

where p_i is the price of good i, with $i, j = 1, 2, ..., n$, w_j is the wage paid, l_{lj} is the amount of labour of skill class $l = 1, 2, ..., m$ and r_j is the cost of capital. The amount of capital required per unit of output is k_j. The key parameter for input-output (I-O) analysis is a_{ij},

[9] It is best not assume that any developing country has “idle capacity” in the Keynesian sense of a depression economy. Everyone is working, by and large, but the problem is that their productivity is low, especially in the informal and subsistence sectors. It is not zero, however, and this sets up a choice problem that must be carefully analyzed by policy-makers. Anecdotal evidence suggests that some young and fit workers in South Africa have never entered the labour force–in the sense of looking for a job–and have become accustomed to living on transfers. Employment policies that fail to take into account the opportunity cost of leisure, in this example, could become sorely frustrated.

the amount of good i required as an intermediate or raw material for the production of one unit of good j.

Capital and labour coefficients are usually considered to be variable over time and across sectors. The coefficients depend on the wage-rental ratio, w/r, for each skill category of labour. Given that ratio, firms choose a combination of capital and labour that minimizes the cost to produce the level of output X_j. The key assumption for I-O analysis is that, while factor proportions vary with the wage-rental ratio, the a_{ij} proportions of the intermediate and raw material inputs do not.

Is this a reasonable assumption? Consider a dam project implemented to solve a combination of excess demand for electricity, protecting a flood plain from environmental devastation, enhancing upstream transportation and recreational facilities and managed access to irrigation. The basic I-O assumption can be translated as follows: there are various ways in which the dam can be built, using more labour- or capital-intensive methods. The project design can specify a large number of earth-movers and backhoes or literally an army of workers with more rudimentary equipment. What project design *cannot* do is to change the amount of high-strength cement necessary to retain peak-flow frontal forces on the dam. While labour can be substituted for capital, no quantity of backfill can safely replace the concrete, an intermediate good. Substitution is *technically* unfeasible.

However, this is not always the case. Consider the example of asphalt versus concrete road paving or construction projects, both technically feasible. One of the two inputs may have to be imported, while the other may be produced locally. How can this be handled in the I-O framework? The traditional answer is to introduce *alternative processes*, that is, two columns of inputs that differ in ways that reflect the locality of input sources. Straightforward optimization would select the cheapest, given wages, the cost of capital and the exchange rate. Policy-makers, however, may elect to choose the employment-maximizing technique. In this case the I-O model can answer the question of how much loss was incurred when the policymaker made the "wrong" choice.

It is therefore common to use "fixed coefficient" technologies for intermediate goods when employing I-O models, letting factor returns adjust to an unspecified level of capital and labour employed "behind the scenes". In this approach, it is not absolutely necessary to distinguish the wage, w, from labour demand, L, and the rate of return to capital, r, from the demand for capital, K. One only sees the wage bill and the payments to capital.

I-O thus focuses on the part of the economy it can handle best–fixed, blueprint-guided relationships between specific inputs–while ignoring much of the detail in factor markets. This particular recipe has made I-O analysis the most successful and widely used model economists have ever devised for impact analysis of large projects, i.e., greater than or equal to one per cent of gross domestic product (GDP).

However, it is not necessarily successful in capturing the detail of the labour market. An economist with a positive disposition would say that I-O analysis is therefore compatible with whatever labour market model one wishes to use. Its only requirement is that the wage bill, the product of wages times labour demand, be made available to the model.

Any model of labour market dynamics would have to include both skilled and unskilled components. As argued in Interdisciplinary Research Consultants (2014), the skill composition is time-phased by the technology. In the example of the dam, highly skilled engineers are necessary at the beginning of the project and more unskilled labour is necessary as the construction phase proceeds. The total wage bill may be constant throughout the period, but its composition changes dramatically. The choice point is still between machinery and labour and not in the time-sensitive application of skilled and unskilled labour. If labour were considered a vector of demand for different skills and experience, the internal proportions of the vector and how they change over time would be determined by the project itself.

What appears as highly restrictive assumptions of linearity and fixed-coefficients is somewhat finessed in this way by skilled practitioners of the I-O art. The art, however, is perishable and does not always withstand the passing of time or a burst of technological change. China has had to adjust in this way as it nears the Lewis turning point, that is, the point on the labour supply curve at which it abruptly turns upward, indicating that labour is no longer in perfectly elastic supply. As argued in Interdisciplinary Research Consultants (2014), there may exist a labour "hop scotching" phenomenon, in which the educated children of unskilled workers are able to bypass middle-level opportunities in construction and other trades for better jobs as professionals, at home and abroad. As labour markets adjust, wages for middle-level jobs would rise to reflect the scarcity brought about by this process. All this complexity can be more or less guided by the control totals of a well-designed I-O study, enriching both frameworks, the detailed labour market analysis and the macro-level impact of the PIP.

By far the most attractive feature of I-O models is their ability to account for economy-wide effects of project implementation. A dam project is said to "pull" on inputs, both domestic and foreign, which in turn pull on their own suppliers. How this works is easy to see if the example of the dam construction is kept in mind. The $n \times n$ matrix

$$A = \begin{bmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \\ \vdots & \vdots & & \vdots \\ a_{n1} & a_{n2} & \dots & a_{nn} \end{bmatrix} \tag{3}$$

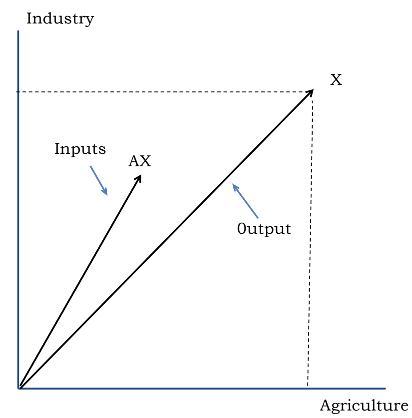
is the I-O *coefficient* matrix describing the amount of good i required for one unit of the production of good j, as noted above. These are the *flow* coefficients and have embedded in them the fixed-coefficient assumption already discussed. The total demand for intermediate goods is an $n \times 1$ matrix, or column vector.

$$AX = \begin{bmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \\ \vdots & \vdots & & \vdots \\ a_{n1} & a_{n2} & \dots & a_{nn} \end{bmatrix} \begin{bmatrix} X_1 \\ X_2 \\ \vdots \\ X_n \end{bmatrix} \tag{4}$$

which is the same as $\sum_{j=1}^{n} a_{ij}X_j$. Figure 1 shows the output and input vectors for a two-sector economy, agriculture and industry. This economy is *productive* since its inputs are bounded from above by the dotted lines. If the inputs were greater than either or both upper bounds, some level of *imports* would be indicated.

Figure 2 shows the essence of the I-O model. As inputs are required for the outputs, so too are inputs required for the inputs themselves. This is shown in the figure as the even shorter vector labeled A^2. The process continues ad infinitum but practically only to the point that the level of inputs for that round is indistinguishable from zero. The sum of these vanishing vectors is known as the *direct and indirect requirements* for the production of X. This beloved concept among practitioners of I-O analysis shows that it is not possible in modern economies to produce anything without effectively rippling through the *entire* economy, for both output and employment.

Figure 1: Vector diagram of the I-O model–inputs must be $\leq$ outputs for a closed economy



How then is X itself determined? It can be deduced from what is known as the *material balance equation* of the I-O framework. Implicitly define the vector of *final demand*, F as

$$\begin{bmatrix} X_1 \\ X_2 \\ \vdots \\ X_n \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} & \ldots & a_{1n} \\ a_{21} & a_{22} & \ldots & a_{2n} \\ \vdots & \vdots & & \vdots \\ a_{n1} & a_{n2} & \ldots & a_{nn} \end{bmatrix} \begin{bmatrix} X_1 \\ X_2 \\ \vdots \\ X_n \end{bmatrix} + \begin{bmatrix} F_1 \\ F_2 \\ \vdots \\ F_n \end{bmatrix} \tag{5}$$

This expression can be written more compactly as

$$X = AX + F$$

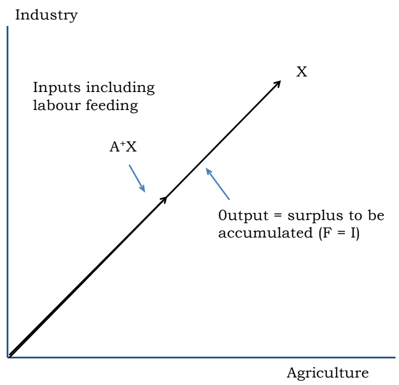
where F is shown in figure 3 as the *difference* between X and AX. There are many ways to solve this last expression for X as a function of final demand, F. In the early days of the Soviet Union they did it with buildings full of computers, literally women armed with pencils and paper, but now it can be done by matrix inversion methods available even in Excel. A more instructive solution is the so-called power-series expansion or approximation to the solution that involves successive powers of A multiplied by the final demand vector F

$$X \sim F + AF + A^2F + \ldots + A^nF \tag{6}$$

which provides the basis for quick computation of X given F in virtually any programming language.[10] In words, this expression says: to produce F one needs also to produce inputs for F and then inputs to produce the inputs for F and so on. The gross output, X, is then the sum of these inputs plus the quantity of F itself.

[10]The classic reference, Dorfman et al. (1958), is still the best since it shows the close connection between economic theory and the I-O framework.

Figure 2: Vector diagram of the I-O model– note the shrinking size of the input vectors as they chain and sum to the direct and indirect input requirements for the given value of X



To see how a dam project might affect this economy, raise the *second* coefficient in the vector F by an amount ΔF_2, the planned expenditure during the period[11]

$$\begin{bmatrix} F_1 \\ F_2 + \Delta F_2 \end{bmatrix}$$

Note that F is a compact way of writing the more familiar national income and product accounting equation

$$F = C + I + G + N_x$$

where C is consumption (including imports), I is the sum of structures, equipment, residential construction and change in inventories undertaken by both private and public sectors, G is current government consumption and N_x is net exports, exports minus imports. When the dam is built, it will enter final demand as investment (assuming it takes less than or equal to one year).[12] It will then begin to pull on its intermediate inputs, which in turn pulls on theirs in an infinite but asymptotic chain.

3.1. Employment in I-O models

With data in hand on the wage bill for the dam project (subject to the caveats mentioned above about its composition) one can perform an employment impact assessment of the project.[13] Without the aid of the conceptual framework developed so far, one might be tempted to write the employment total, $\mathcal{L}$, as

$$\mathcal{L} = LF = \sum_{i=1}^{n} l_i F_i$$

where $L = [l_1, l_2, ..., l_n]$ is a row-vector of labour coefficients or ratios of the employment to the level of gross outputs of each sector, derived from the base SAM in which wages and prices are conventionally set to one. This would, however, be incorrect since it omits the employment generated by the production of the inputs for F. It also omits the inputs to produce the inputs and so on, as just discussed. The correct expression for total employment is

$$\mathcal{L} = LX = \sum_{i=1}^{n} l_i X_i > \sum_{i=1}^{n} l_i F_i.$$

[11] A numerical example of precisely this PIP shock is given below.
[12] If not, the stimulus is spread over the entire project period as seen in the example below.
[13] The concepts explained in this section will apply to Social Accounting Matrices, SAMs, both static and dynamic, that are discussed in the next sections.

The employment *impact* in the case of the dam, $\Delta\mathcal{L}_d$, can be written as

$$\Delta\mathcal{L}_d = [l_1 l_2]\left[\begin{bmatrix}1 & 0\\0 & 1\end{bmatrix} + \begin{bmatrix}a_{11} & a_{12}\\a_{21} & a_{22}\end{bmatrix} + \begin{bmatrix}a_{11} & a_{12}\\a_{21} & a_{22}\end{bmatrix}^2 + \cdots + \begin{bmatrix}a_{11} & a_{12}\\a_{21} & a_{22}\end{bmatrix}^n\right]\begin{bmatrix}0\\\Delta F_2\end{bmatrix}$$

The change in direct employment due to the dam project is $\Delta\mathcal{L}_{d'}$, is

$$\Delta\mathcal{L}_{d'} = [l_1 l_2]\begin{bmatrix}0\\\Delta F_2\end{bmatrix}$$

whereas the change in direct plus indirect employment is $\Delta\mathcal{L}_d$.

3.2. Closed and open I-O models

Closed and open I-O models are usefully distinguished (Ernst and Sarabia, 2015), primarily because the former reveal the inner workings of the multiplier. The model above is open but a closed model would include coefficients for consumption as well as intermediates. These are known as *labour-feeding coefficients*, c_{ij},

$$c = \begin{bmatrix}c_{11} & c_{12} & \dots & c_{1n}\\c_{21} & c_{22} & \dots & c_{2n}\\\vdots & \vdots & & \vdots\\c_{n1} & c_{n2} & \dots & c_{nn}\end{bmatrix}$$

which measure the amount of good i labour must *consume* to produce one unit of *labour*. In some sense this is an odd concept, but again the coarse-grain nature of I-O modeling allows for a large amount of detail to be built in, ex post. Total consumption demand for this economy is

$$\mathcal{C} = cLX$$

Here equation 5 above, the material balance equation, can be altered to include the labour-feeding coefficients by replacing A with

$$A^+ = \begin{bmatrix}a_{11} & a_{12} & \dots & a_{1n}\\a_{21} & a_{22} & \dots & a_{2n}\\\vdots & \vdots & & \vdots\\a_{n1} & a_{n2} & \dots & a_{nn}\end{bmatrix} + \begin{bmatrix}c_{11}l_1 & c_{12}l_2 & \dots & c_{1n}l_n\\c_{21}l_1 & c_{22}l_2 & \dots & c_{2n}l_n\\\vdots & \vdots & & \vdots\\c_{n1}l_1 & c_{n2}l_2 & \dots & c_{nn}l_n\end{bmatrix}$$

which can be compactly written as

$$X = A^+X + F$$

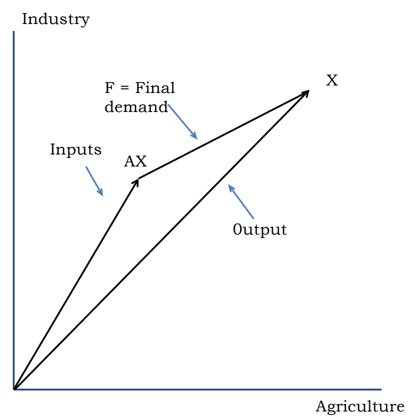
where $A^+ = A + CL$. The system can then be solved for a given level of final demand, F.

$$X \sim F + A^+F + (A^+)^2F + ... + (A^+)^nF$$

The rest of the employment analysis follows in the wake of this rather fundamental change in the nature of the model. The labour-feeding coefficients, c_{il}, are not easy to estimate and embody an unrealistic assumption, namely, that workers do not adjust their consumption bundle in response to changes in the macro economy, whether incomes or prices. So far, of course, there are no relative prices in the I-O model and so one could presumably sleep soundly, even after making this assumption. More realistically, side calculations could be made by hand on the time-path of the c_{ij} coefficients as relative prices do in fact evolve.

What workers require to live and keep working admittedly suggests an excessively rigid vision of the economy, but there is one attractive feature of the closed model that could in principle be used to establish an upper bound for the impact of an investment project shock. Figure 4 shows that F, A and A^+X are all collinear and this corresponds to the maximal rate of growth of the closed system and therefore the maximal rate of growth of employment.[14] Employment in the economy is $\mathcal{L} = LX$.

Figure 3: Vector diagram of final demand in an I-O model



3.3. Prices and dual of the material balance

Since the I-O model is a matrix, it can be viewed either as a "stack" of rows or a "rack" of columns. Viewing the problem from a row perspective gives a material balance, a balance between supply and demand. The price level for each row is given by

$$PX = PAX + PC + PI + PE - eP^*M \tag{7}$$

where $P = [p_1, p_2, ..., p_n]$, A is the I-O coefficient matrix, $C = [C_1, C_2, ..., C_n]'$ is the consumption column vector, $I = [I_1, I_2, ..., I_n]'$ is the level of investment[15], $E = [E_1, E_2, ..., E_n]'$ is exports and $M = [M_1, M_2, ..., M_n]'$ is the level of imports. The nominal exchange rate is given by e and the price of imports is P^*. Here PAX is intermediate demand and $PC + PI + PE - eP^*M$ is final demand. Factor demand for labour is denoted $L = [L_1, L_2, ..., L_n]$ and capital is given by $K = [K_1, K_2, ..., K_n]$. Value added, V, is then

$$V = PX - PAX = wL + rK$$

where w is the wage rate and r is the rate of return to capital. Value added must equal the value of final demand since

$$PF = PX - PAX$$

[14]The eigenvector associated with the maximal eigenvalue gives the proportions for balanced growth along this von Neumann turnpike. The surplus over and above the technical and labour-feeding coefficients, $S = (I - A^+)X$ is itself a vector of goods that may be consumed, invested or exported. Only if *all* the surplus is reinvested will a closed economy grow at its fastest sustainable rate.

[15]The apostrophe indicates vector transpose.

Table 1: I-O framework

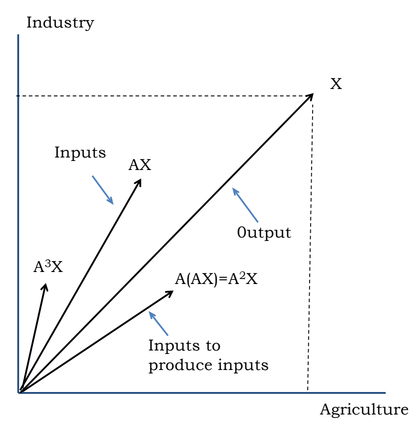
	Agriculture	Industry	Consumption	Investment	Government	Exports	Total
Agriculture	10	8	30	5	15	10	**78**
Industry	20	12	40	8	15	-5	**90**
Value Added	48	70	-	-	-	-	-
Labour	30	42	-	-	-	-	-
Capital	18	28	-	-	-	-	-
Total	**78**	**90**	**70**	**13**	**30**	**5**	-

- = N/A
Millions of LCUs.
Source: Authors' computations based on illustrative data.

or $V = PF$. It should be clear from this discussion that I-O is less of an economic model than it is a framework to record the *data* of an economy; in other words, a highly structured data-base.

Columns of the matrix require prices since, reading down the columns of the I-O matrix, the goods are heterogeneous and must be aggregated by the price vector. To this nominal value is added the return to labour, wL, and the return to capital, rK, which are both measured in nominal terms. This suggests that the entire presentation of the I-O framework must be in *nominal* terms. If a given I-O system is also compiled for a *base year*, the values in the structured data base are both real *and* nominal. As noted above, it is convenient to normalize all prices to one for the base year, along with the base year wage rate. The units of X are then in millions of LCUs and if prices were to rise by, for example, 15 per cent, it could be said that PX is the *cost of what could have been purchased in the base year* with one-million LCUs of the base year. This is a useful convention in I-O accounting and widely adopted.

Figure 4: Vector diagram of balanced growth with maximal employment growth



In table 1 there are two sectors, industry and agriculture. Here the GDP, computed as the sum of value added in both sectors, is 48+70 = 118. Assume, unrealistically, that the dam can be constructed in one year and that its construction requires an expenditure of one per cent of GDP, the minimum the framework is capable of seeing. This is 1.18 million LCUs and is added to the level of investment demand for industry.[16] In the I-O framework this rise

[16]Keep in mind that the investment above is investment by *origin* and not destination. The former is a component of aggregate demand whereas the latter is an increment in the capital stock.

Table 2: A dam project in the I-O framework

	Agriculture	Industry	Consumption	Investment	Government	Exports	Total
Agriculture	102	8.12	30	5	15	10	**78.1**
Industry	204	12.19	40	9.18	15	-5	**91.4**
Value added	48.09	71.09	-	-	-	-	-
Labour	306	42.66	-	-	-	-	-
Capital	18.03	28.44	-	-	-	-	-
Total	**78.1**	**91.4**	**70**	**14.2**	**30**	**5**	-

- = N/A
Millions of LCUs.
Source: Authors' computations based on illustrative data.

in aggregate demand gives direct and indirect effects on the both sectors as seen in table 2.

From table 2 it is evident that investment has risen from 8 to 9.18, or one per cent of GDP. This change causes direct and indirect effects on both industry *and* agriculture precisely in the fashion described in the mathematical model above. This is the simplest possible model inasmuch as consumption remains fixed and only intermediate demand rises in response to the PIP shock. In particular, the capital and labour components of total value added rise proportionately. The demand for labour increases according to labour coefficients calculated from the base (30/78 for agriculture and 42/90 for industry). The same occurs with capital in this entirely linear model.

The example identifies the limitations of the linear I-O model as a framework for analysing the impact of PIPs on the demand for labour. It is unrealistic to think that the cost of capital will rise proportionately with output in the short run. It might be better to have the capital fixed in the short run so that the cost of capital itself remains fixed. In the short run, output increases in both sectors, but employing more workers with the same amount of capital is satisfied by the rise in demand.

How does the demand for labour actually change when a PIP is introduced? In the short run, capital is fixed, as is the nominal wage rate. The assumption is that the project managers will employ labour until the value of its marginal product is just equal to the real wage. Any other assumption would violate the most basic principles of profit maximization, implicitly allowing firms to employ more or less labour than they need.

When Ernst et al. (2015) suggest that "satellite" models can be constructed to evaluate the impact of project investment on the economy, they mean that one of the most crucial assumptions for the construction of a satellite model is that there should be a "representative firm" for the satellite that shows how it reacts to the PIP shock. This will allow for a more realistic non-linear response to the increase in demand. The satellite model must be consistent with the value added in the I-O model.

Assume first that the industrial sector production function is given by

$$p_j x_j - \sum_{i=1}^{n} p_i a_{ij} x_j = \mathcal{A}_j K_j^{\beta_j} L_j^{1-\beta_j} \tag{8}$$

where $\mathcal{A}_j$ is an arbitrary calibration constant that can be used to model technological change or spending on environmental protection. Here K_j is the capital employed by the industrial firm and L_j is the labour. Nominal value added, v_j is given by

$$v_j = p_j x_j - \sum_{i=1}^{2} p_i a_{ij} x_j$$

Since this is a Cobb-Douglas production function, the marginal products for capital and labour, respectively are

$$\begin{aligned} \beta_j v_j / K_j &= r \\ (1-\beta_j) v_j / L_j &= w \end{aligned} \tag{9}$$

where for the moment, w and r are common to all sectors. Under the standard neo-classical assumption that a rational firm would employ labour until the value of the marginal product of labour is equal to the wage and the value of the marginal product of capital is equal to the cost of capital, these two equations can be rearranged to yield

$$\begin{aligned} \beta_j &= r K_j / v_j \\ (1-\beta_j) &= w L_j / v_j \end{aligned}$$

The right-hand side in both cases is the share of the factor in the value of total production, precisely what is shown in the last two rows of the I-O matrix in table 1. In this case

$$\begin{aligned} \beta_1 &= 18/(18+30) = 0.375 \\ \beta_2 &= 28/(28+42) = 0.4 \end{aligned}$$

Once the share of capital, β_j is estimated, the share of labour can be deduced from the assumption of constant returns to scale (that the exponents in the production function add to one). The labour shares are

$$\begin{aligned} 1-\beta_1 &= 0.625 \\ 1-\beta_2 &= 0.6 \end{aligned}$$

where it is seen that the factor shares are similar between the two branches of production.

Why is the Cobb-Douglas production function used here? Observe that the "adding-up" feature of the Cobb-Douglas is fully consistent with the I-O framework and can be easily calibrated from data of the matrix. Here the structure of the data determines the production function. There is no real reason why the exponents would necessarily add to one, but if the Cobb-Douglas is to be consistent with the I-O structure, it must.

This is one of many examples in which the *structure* rather than the data determines, *or limits*, what can be said using a model. One of the reasons that I-O is so popular in the developing world is that it imposes strict constraints on what the data can say. This can be seen as both a benefit and a cost of the method.

If the percentage is given in the short-run, the year for which the data is collected, but labour is variable and determined by the marginal productivity condition, the firm is on its rising marginal cost curve. Any increase in output then must be accompanied by a rise in demand for labour. As output x_i rises so too does v_i. Equation 9 shows that the marginal product of labour and capital rise proportionately. In the case of labour, employment rises and the wage rate is fixed. For capital, however, the quantity is fixed and thus the rate of return rises above the market rate. The assumption of the short run drives this result but as capital invested changes in the next period, the model is in a new "short-run" for which the same logic applies.

Equation 3.2 shows how the new values of X can be computed. The base level is given by

$$\begin{bmatrix} 78 \\ 90 \end{bmatrix} \sim \left[\begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} + \begin{bmatrix} 0.128 & 089 \\ 0.256 & 0.133 \end{bmatrix} + \begin{bmatrix} 039 & 023 \\ 067 & 041 \end{bmatrix} + \begin{bmatrix} 01 & 01 \\ 02 & 01 \end{bmatrix} + \begin{bmatrix} 003 & 002 \\ 005 & 003 \end{bmatrix} \right] \begin{bmatrix} 60 \\ 58 \end{bmatrix}$$

where this calculation, easily done in Excel, is taken only to the 4th power for ease of exposition.[17] Recall that the rule of thumb for a minimum shock is approximately one per cent of GDP, or 1.18, that would be added to the second component in the F vector to represent the increase in final demand for the dam project.[18] This gives

$$X = \begin{bmatrix} 78.1 \\ 91.4 \end{bmatrix}$$

assuming no change in the price level. The new value added is calculated as the difference between the value of output and intermediate costs at the new level of X, as seen in table 2

$$v_1 = 48.1$$
$$v_2 = 71.1$$

then all the increase in value added must appear as added demand in the labour market and a rise in the rate of return to capital. The increase in employment is calculated as $\Delta L = l_i(x_i - x_{i0})$ where x_{i0} is the base level of output.

$$\Delta L_1 = 06$$
$$\Delta L_2 = 0.66$$

[17] The error is less than 0.2 per cent. Any degree of accuracy could be obtained by extending the power series further.

[18] The model does not "see" small shocks but is just as blind to large shocks that induce sufficient structural change to do violence to the assumed stability of the parameters of production and consumption.

Note that the rate of return to capital also increases slightly, assuming that the capital stock remains fixed.[19]

Here is where detailed knowledge of how the labour markets actually work comes into play in an important way. In the agricultural sector, the increase in the demand for labour is likely to be for unskilled labour whereas in industry, the demand for labour would be more heavily weighted toward skilled labour. It is also true that the *marginal* change in the demand for labour may have little to do with the *average* demand for labour. The role of the I-O analysis is simply to provide *control totals* for both categories of labour. Figure 5 shows a modular analysis of the demand for and supply of skilled labour that has been undertaken in a satellite study.

Figure 5, panel (b) shows the area under the path of the skilled labour demand and supply points as demand for output in that sector rises. This is the value of the wage bill for skilled labour. Subtracting this amount from the value added by labour would give (1) the value of the unskilled labour wage bill; and (2) an estimate of the amount of spending on wages consistent with the I-O system after the demand shock has occurred. The only constraint that the I-O system imposes is the sum of the demand for labour multiplied by the wage rates–prevalent at the time–is equal to the labour value added in the I-O accounts. Total spending on unskilled labour divided by the wage of unskilled labour is the quantity hired.

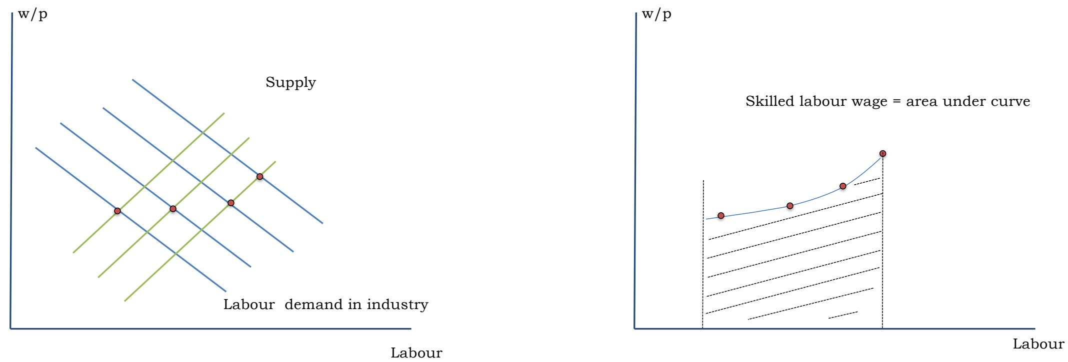
What then happens in agriculture after an exogenous shock to demand in the industrial sector? To the extent that agriculture provides intermediate goods for the industrial sector, demand for agricultural output will increase. If the price of agriculture is fixed by the assumption that agriculture is a competitive sector and the cost of inputs from the non-agriculture sector rises, the agricultural supply curve will shift to the left.

How does a rise in price of the industrial sector affect agriculture? The demand for labour in the agricultural sector is

$$L_1 = (1 - \beta_1)v_1/w \tag{10}$$

and since neither p_1 nor w changes, nominal value added, v_1, is constant. Thus, labour demand is only proportional to output. If intermediate costs rise, then v_1 must fall for the same level of demand. Think of the level of demand as the sum of the elements across the first row of the I-O table, including intermediates. If none rises, but the cost of intermediates increases in row 2, as a result of higher input prices, total value added at the same level of demand, indicated by the row sum, must fall. On the other hand, if a row element does increase as result of a change in the input cost from industry, value added in agriculture will rise and can easily overpower the reduction caused by an increase in the industrial price. The impact on agricultural labour demand in equation 10 above depends on the balance of these forces on v_1, and nothing else. It follows that a steeper rise in price should eventually cause v_1 to fall, and with it labour demand, for the given increase in intermediate purchases

[19]The calculation is tedious but straightforward. First compute K from the Cobb-Douglas equation 8 taking the wage rate as 1 and L from the base matrix. The shares β and $1 - \beta$ are also taken from the base matrix. The result is $K_1 = 105.1$ and $K_2 = 150.6$. The rate of return to capital–or the cost of a unit of capital–can be then calculated for each sector from the fact that rK can be read from the base matrix. This gives $r_1 = 0.17$ and $r_2 = 0.186$. Holding K constant during the shock produces a change in r of 0.172-0.171 = 0.001 and 0.189-0.186 = 0.003 for the two sectors respectively.



(a) Supply and demand for skilled labour undertaken by satellite study

(b) Value of the wage bill for skilled labour

Figure 5: Labour market

occasioned by the exogenous shock of the PIP. Some of this labour will migrate to the industrial sector.

If the market structure in either sector is *not* competitive, the prices can change without a corresponding change in output if costs increase. Competitive firms, on the other hand, cannot increase price even if their costs rise. Their only choice is to leave the industry when their value added falls as a result of a rise in input prices. In a competitive market, prices could change if firms entering either sector are large enough to increase the demand for factors of production and consequently their prices. Excess supply of labour usually prevents much of a change in factor prices, at least with respect to the price of unskilled labour. The case of skilled labour can be quite a different matter.

3.4. Imperfect competition in an industry with a competitive agricultural sector

Any given economy is a mix of competitive and non-competitive elements. Consider for example the case of an economy in which the industrial sector operates under monopolistic competition, while the agricultural sector is competitive.

It is quite likely that a rise in output initiated by a rise in demand for industrial output following a PIP, will drive the industrial price higher. This creates a non-competitive *rent* for capital in that sector as seen above in the rise in the rate of return to capital.

The same may apply to agriculture, but it is instructive to consider the case in which agriculture is a more competitive, price-taking sector, where the price may be fixed by foreign competition, public policy or some other mechanism. As demand drives output higher, agricultural supply increases with no effect on the agricultural price, while in industry the supply curve is upward sloping.

The analysis of a non-price-taking sector proceeds as follows. Let τ be the mark-up on costs such that

$$p_j = (1+\tau_j)\sum_{i=1}^{2}(p_i a_{ij} + w_j l_j) \quad (11)$$

where, for the moment, there is one kind of labour. In the industrial sector above, $\tau = 0.452$, and can be checked by plugging this value back into equation 11 to confirm that $p = 1$. As the level of output rises, the mark-up τ increases, by for example

$$\tau = \tau_0 (\frac{x_i}{x_{i0}})^{\tau_e} \quad (12)$$

where τ_0 is the initial level of the mark-up when output is x_0 and τ_e is an elasticity that is estimated from data in a satellite study. Note that the structure is not imposing much on the data here, allowing the data to speak mostly for itself.

How then does a rise in spending on a dam affect employment in this more complicated economy? Let $\tau_e = 0.5$, so that a one per cent rise in output relative to the base causes a 0.5 per cent increase in the mark-up over costs. In this case, the industrial price rises and causes the value added in the agricultural sector per unit of output to fall, since its price is, by assumption, fixed. Since demand for intermediates has risen, employment rises slightly in both sectors.

Table 3 shows the result of this simulation of the shock with various assumptions about the slope of the supply curve in the industrial sector. Agriculture is considered competitive, so that as firms enter the industrial sector, the agricultural price does not rise. Introducing prices into the framework has a palpable effect on the model. The table shows that as the price response is more vigorous, employment gains are increasingly concentrated in the sector directly affected by the project, industry. Indeed, with an elasticity approaching one, agriculture begins to lose employment. The short-run assumption of a constant capital stock means that the price increase in industry can reduce value added in the agricultural sector to the point that it could *completely cancel the indirect effect of the expansion in intermediate demand from the dam project.* Here again is the mechanism: with a higher elasticity, the price increase in industry is larger. This raises the cost of intermediates for agriculture, leaving a smaller fund from which to hire labour. Eventually this effect overpowers the demand for intermediates and employment.

3.5. Employment and decent work

Prices clearly matter in this economy and to the extent that relative prices adjust, not only is the internal distribution of the demand shock altered, but also the purchasing power of labour also changes. Note from table 3 the consumer price index (CPI) rises by as much as 0.44 per cent.[20] This implies that agriculture no longer offers *decent work*, if indeed, it had in

[20] The concept of real wages is somewhat ambiguous. Nominal wages could be converted to real wages by way of the price of the product, the real *product wage* or by way of the consumer price index $p_c = \frac{p_1 C_1 + p_2 C_2}{C_1 + C_2}$ that is, the wage is deflated by what consumers actually consume.

Table 3: Response to a dam expenditure of 1 per cent of GDP in the input-output model

	Base	Response			
Mark-up elasticity[1]	***0***	***0***	***0.20***	***0.50***	***0.80***
Price					
Agriculture	1	1	1	1	1
Industry	1	1	1.0013	1.0039	1.0077
Real value added	118.0	119.2	119.2	119.1	119.1
Agriculture	48.0	48.1	48.1	48.0	48.0
Industry	70	71.1	71.1	71.1	71.1
Labour demand	72.0	72.7	72.8	72.8	73.0
Agriculture	300	306	304	302	29.99
Industry	42.00	42.66	42.71	42.82	42.99
CPI	1.0000	1.0000	1.0008	1.0022	1.0044
Consumption	70	70	70	70	70
Agriculture	30	30	30	30	30
Industry	40	40	40	40	40
Real wage[2]					
Agriculture	1.000	1.000	0.999	0.998	0.996
Industry	1.000	1.000	0.999	0.998	0.996

[1] Price response to a rise in output at various elasticities. with Fixed consumption. [2] Nominal wage deflated by consumer price index (CPI) using consumption weights.
Source: Authors' computations.

the past. Real wages fall and all the increased employment that should have followed the fall in the wage rate evaporates in agriculture. The real product wage is constant in agriculture while the real wage there is lower. In the industrial sector both real wages and real product wages are lower, but at least the improvement in employment offsets the decline in decent work there.

The simple model produced so far holds consumption constant. Despite lower real wages, consumption remains fixed at the level of the base data in table 1. For small changes this might be an acceptable first approximation, but as the effect of the PIP increases above a threshold, household savings could easily turn *negative*. This threshold, moreover, may be *lower* than the one per cent of GDP that is used in this example. It cannot be known until an explicit check on that possibility is built in. In the next section, a SAM is introduced that accounts for households' income and expenditure including the amount they save.

This more sophisticated approach opens many doors. The linearity of the I-O model admits no substitution between inputs and outputs in production, despite whatever change there may be in relative prices. This simplifying assumption in production is wholly untenable, however, when it comes to households. Unlike blueprints, or the labour-feeding model discussed above, households will *substitute* out of expensive goods and increase their budget shares spent on cheaper goods. This could easily allow them to maintain positive savings and may go some way to restore the decency of work in both sectors that was diminished by the rise in prices.

Note that I-O analysis also has little to say about *factor* substitution. In this case, both sectors have become more labour intensive simply because labour can adjust more rapidly than capital. Still, substitution is highly limited and can only be treated properly by way of dynamic SAMs, as seen in section 5.

4. SAMs and CGE models

Table 4 shows a SAM built around the I-O model of table 1. It fills in the income and expenditure balance for the four *agents* of the model, firms, households, government and foreign. This SAM is a simplification of more elaborate SAMs that appear in the literature, but nonetheless captures the essence of how a SAM-based model can improve on the I-O framework.

Table 4: Social Accounting Matrix (SAM)

	Agriculture	Industry	Consumption	Investment	Govt	Exports	Total
Agriculture	10	8	30	5	15	10	**78**
Industry	20	12	40	8	15	-5	**90**
Value Added	48	70	-	-	-	-	**118**
Labour	30	42	-	-	-	-	**72**
Capital	18	28	-	-	-	-	**46**
Savings	-	-	38	-	-20	-5	**13**
Taxes	-	-	10	-	-	-	**10**
Imports	-	-	-	-	-	-	**0**
Total	**78**	**90**	**118**	**13**	**10**	**0**	

- = N/A.
Millions of LCUs.
Source: Authors' computations based on illustrative data.

A SAM is not a model, but rather a data base that is coherent, if and only if it is *balanced*. A balanced SAM implies that all four agents of the SAM are in income-expenditure balance. As a mathematical property of matrices (the proof is straightforward but beyond the scope of this paper) income-expenditure balance also implies that the sum of savings for these four agents must be equal to investment.[21] The sum of savings equal to investment is a property of square matrices and imposes structure on data that could be said to have come from theory. Many behavioral models can be calibrated to a given base SAM and choice of additional detail usually has important effects on the estimates of employment derived from the I-O model.

4.1. Firm income and expenditure

Firm income derives from sales to all four agents in the model. Equation 5 above lists the categories of expenditure that contribute to firm income, essentially intermediates plus final demand. Firm expenditure is listed down the first column of the SAM and is divided into purchases of intermediates and value added. In more complicated SAMs, firms save and pay direct and indirect taxes to government.[22]

Firms sell output to all categories of demand including investment. As noted above, investment that enters the SAM in the first row is investment by *origin* and it is not known from the SAM how that quantity will be distributed across productive sectors for the purposes of capital accumulation. This latter is investment by *destination*, equal in magnitude to the sum of investment by origin, and will be taken up in detail below.

SAMs are balanced in practice by choosing a "residual" item for the row-column pair for each agent. The residual item in the income expenditure balance for firms is often value added and if the assumption of the short run can be maintained, such that labour costs are known, the residual is just the expenditure on (or return to) capital. This point is key to understanding how labour market analysis can be cogently addressed in the context of CGE/SAM models. If labour demand is determined by the marginal productivity condition, then profit becomes the residual for firms and thus the return to the capital item in the SAM includes both profit and *rent* as the total return to capital.

4.2. Consumer income and expenditure

The consumer's expenditure depends on income from all sources, including payment from firms in the form of value added and transfers from government. Expenditure also depends on taxes and savings and can be written as

$$E_i = Y_i(1 - t_i)(1 - s_i) \tag{13}$$

[21] This is known among economists (not mathematicians) as *Walras' Law*.

[22] More complex and detailed SAMs often include a row and column for activities. It is simpler and often very accurate to assume that each firm produces only one product and therefore what is known as the "make" matrix reduces to a diagonal matrix. The implication is that there is no "joint" production and this assumption is maintained throughout for the significant simplicity it brings.

where E_i is expenditure, Y_i is total income, t_i is the direct tax rate and s_i is the savings rate of consumer class i. In what follows, the income class subscript will be suppressed for simplicity.[23] In the SAM above, total income is 118 and total expenditure is 70. The tax rate $t = 10/118$ and the savings rate is $s = 38/108$. [24]

Total expenditure of equation 13 is in nominal terms. A simple but perhaps not entirely appropriate way to model the consumption is the Stone-Geary linear expenditure system (LES).[25] This system assumes that the budget shares, m_j, the proportion of expenditure for each good, are *constant*. The propensities to consume are then given by

$$m_j = C_j / \sum_{i=1}^{n} C_i$$

where C_i is consumption from the SAM and $\sum_{j=1}^{n} m_j = 1$.[26] If these proportions are applied to total expenditure, the consumption function intercept will be *zero* since total expenditure will be equal to total consumption. To avoid this, the LES assumes that there are fixed intercepts and defines *supernumerary* expenditure, E^+, as

$$E^+ = E - \sum_{i=1}^{n} p_i \theta_i$$

where p_i is the consumer price and θ_i is the intercept, one for each household or social class[27] The *linear expenditure system* can be written as

$$p_i C_i = p_i \theta_i + m_i E^+ \tag{14}$$

4.3. Government income and expenditure

Government income is from taxes, shown in the SAM of table 4 as 10. In general, the government accounts are vastly more complex in an actual SAM, but the concepts are themselves straightforward. Government can collect income in the form of direct and indirect taxes on all agents of the model, including themselves.

Government expenditure is listed in the column of the base SAM and is disaggregated into expenditure on goods and services from agriculture and industry. Not shown is the often crucial government employment account, which has been omitted for conceptual clarity. Government wages are paid as a value added component to households and thereby included,

[23] Colombo (2010) shows how microsimulations can be slotted into the CGE framework. In principle, any size consumption matrix–even those derived from income surveys of tens of thousands of households–could be substituted for the consumption matrix, C, in the SAM. The size is only limited by computational capacity. Note that there are various adding-up constraints discussed by Colombo (2010), such as consistency with national income and product accounts. The inclusion of microsimulation models in CGEs is beyond the scope of this paper and the reader is referred to what is now a voluminous literature on the topic, surveyed in Colombo (2010).

[24] Note that savings is out of *disposable* income.

[25] The 2015 Nobel prize in economics given to Angus Deaton was, in part, for his criticism of the LES. His *almost ideal demand system* (AIDS) allows more substitution than the LES but also is more data intensive.

[26] Note that $\sum_{i=1}^{n} C_i$ is then total consumption in the national accounts.

[27] Recall that the class subscript has been suppressed. There is one E^+ for each class in the model.

along with transfers and income from government debt obligations, in household income. These elements are all set to zero in table 4. The residual item in the government accounts is government savings, income minus expenditure, and is frequently negative.

The SAM above is silent on whether total savings determines investment (savings driven) or whether the SAM has been balanced taking the level of investment as predetermined (investment driven). This choice of "closure", that is, which of these driving mechanisms predominates, is a choice of model structure and adjustment mechanisms and cannot be read directly from the SAM. There is an expansive literature on the closure question and this paper takes the *Keynesian* view that aggregate income and expenditure are driven by firms' investment decision. The opposite view is not invalid, but it is more difficult to explain to policy-makers the many twists and turns required to have aggregate savings determine investment through an analysis of the banking system.

Models of employment based on CGEs that are *savings driven* are crippled by the assumption that government savings enters into the financing of investment with a negative sign. A rise in expenditure on current account will therefore reduce investment pari passu, biasing downward the positive impact that the spending may have had in a recessionary period. There is no reason to assume that government expenditure will always contribute with great aplomb and foresight to future employment opportunities, but the assumption that it will never help is just as one-sided.

Here this debate is conveniently sidestepped by the choice of a dam as the PIP. A dam or any other public infrastructural project does not enter anywhere in the government row or column and therefore can have no effect on government savings, positive or negative. The PIP enters into investment and is usually financed by borrowing, either in domestic, foreign or concessionary markets. The *public sector borrowing requirement* (PSBR) lumps this investment into a grander total and is certainly to be paid attention to in analyzing the salubrious/injurious impact of government on the rest of the economy. It is not presumed to have an injurious impact on private spending, as might other entries in the government expenditure column. These points must be borne in mind when considering the simulations presented below, simulations which by their nature cannot claim to be telling a complete story.

The Keynesian nature of the model this paper–investment driven–imply that a rise in investment could *never* reduce aggregate demand. Still, proponents of the savings-driven approach sometimes maintain that public sector investment projects could, in principle, have a negative impact on the growth if they "crowd out" private investment to the extent that *total* investment falls. These arguments are supported by inter-temporal optimization optimization models, and the proposition known as Ricardian equivalence suggests that future tax liabilities cause current spending to fall, crowding out consumption as well.

Is the choice of an investment driven model arbitrary or suggested by the data itself? Table 5 has been referred to in many papers on the topic as a summary of the effects of infrastructure on employment and the effect on growth has similar empirical support. These results seem highly damaging to the savings driven view. Dintilhac et al. (2015) provides a comprehensive review of the literature on the effect of infrastructure on growth and employment, including

Table 5: Employment elasticities with respect to infrastructural investment

	Elasticity[1]
Central and SE Europe	0.2
East Asia	0.1
SE Asia and Pacific	0.4
South Asia	0.3
Latin American and Caribbean	0.5
Middle East	0.7
North Africa	0.7
Sub-Saharan Africa	0.5

Dintilhac et al. (2015). [1] 2004-2008.
Source: Estache and Garsous (2012).

several exhaustive meta-studies. They note, for example, that Straub (2008) considers 140 specifications from 64 empirical papers. She writes

> What is the global picture coming out of the research surveyed here? Overall, 63 per cent of the specifications find a positive and significant link between infrastructure and some development outcome, while 31 per cent find no significant effect and only 6 per cent find a negative and significant relationship.

This study is only the tip of the iceberg and Dintilhac et al. (2015) present the results of many others concluding

> ... although evidence shows that infrastructure has a significant positive impact on economic growth, the magnitude of the impact depends on the type of infrastructure, the development stage of the country, and the quality of its regulations and institutions. Overall, the elasticity of infrastructure to growth is the highest for the telecoms sector followed by energy. The evidence is mixed for water and sanitation and transport ...

They find a similar outcome for the effect of infrastructure on employment and quote table 5 above from Estache and Garsous (2012). The effect of infrastructure on growth and employment seems to be one of the stylized facts of development economics. Models built on crowding out or some other unsupported mechanism struggle to obtain empirical validation and policy-makers would be ill-advised to bet on any of these contrary mechanisms.

China has done exceptionally well with the infrastructure-drives-growth model as have the other rapidly growing Asian economies, while Haiti suffers from the opposite. When government declines to provide infrastructure, either by omission or by dint of a poorly designed project, and the infrastructure does not materialize one can safely conclude that no stimulus to growth will occur as a result.[28]. The reader is reminded that in economic theory one

[28]Standard textbooks include a gestation period in which congestion caused by infrastructural projects causes GDP to temporarily fall, but never consider the case in which more infrastructure leads to decline in economic performance in the long

of the primary justifications for the existence of government in the first place is to provide public goods, goods that will not be offered by the private sector because of the non-rival and non-excludable nature of public goods.

Whatever the choice of closure, the income-expenditure balance for government can be written as

$$S_g = \sum_{i=1}^{m} t_i Y_i$$

where S_g is government savings and t is the tax rate, 10/118, above.

4.4. Foreign income and expenditure

Foreign income is derived from imports, known in the jargon as either *competitive* or *non-competitive*, depending on whether they substitute directly for local production or are complementary to it. The Atlas method was introduced by the World Bank to exclude wild swings in reported income as exchange rate variation ballooned the import component of GDP and there is little that can be done otherwise to confront this problem. Exports can be less of a problem in this regard since they are priced either as goods consumed domestically (the large country assumption) or at a given world price converted at the current exchange rate (the small country assumption).

Foreign savings is defined as foreign savings in “our” country, not the total amount of savings foreigners undertake. As such it corresponds to the foregone consumption they could have enjoyed if our country had paid for imports with exports. This somewhat counterintuitive idea is expressed mathematically as

$$S^* = \sum_{i=1}^{n} ep^* m_i X_i - p_i E_{ni}$$

where S^* is (nominal) foreign savings, e is the nominal exchange rate and p^* is the foreign price. Non-competitive imports, m_i, is set to zero here and E_{ni} is exports *net* of competitive exports. Foreign savings is the amount foreign debt grows in each period and therefore cannot have a long-term trend that is either positive or negative (China notwithstanding). It serves in CGE models as a measure of the long-term “bad” effects that “good” or expansionary employment policies bring about.

4.5. Labour market dynamics

Labour demand in each period is given by equation 10 for agriculture and similarly for industry.

run (Gruber, 2011)

$$\sum_{i=1}^{2} L_i = \sum_{i=1}^{2} (1-\beta_i) v_i / w \tag{15}$$

Here β is taken as given (from the base SAM or I-O matrix) and w is set exogenously usually in order to be consistent with the time-path of inflation in the actual economy. More complex labour market dynamics can be built into the model and must necessarily be brought to bear, with the introduction of the informal sector as discussed below. If econometric studies corroborate, a wage adjustment equation can be included that ties nominal wages to rates of unemployment, as in the Philips curve. These relationships are notoriously unstable however, and including an endogenous wage equation can do more harm than good in constructing accurate forecasts. If a wage equation is used, the results are regarded only as indicative, since estimates of the supply and demand for labour rarely consort to produce a realistic wage rate. Wages are, therefore, often used parametrically so that policy-makers can see how different adjustment paths lead to different labour market and other macroeconomic outcomes, principally inflation as just mentioned.

Dual labour markets often used to model an informal sector and this approach is discussed in more detail below. It can be assumed that as the formal sector expands, however, workers will move quickly to fill the openings in whatever sector for which they are qualified. Formal employment offers significant advantages, not only in wages, hours and stability, but also in human capital acquisition and other non-wage benefits. In CGE models appropriate for developing countries, the elasticity of supply is usually high, even unboundedly so. This is the dual of the existence of a robustly populated informal sector, the full employment assumption and a relatively high income elasticity in the demand for leisure.

4.6. Using the model for simulating employment effects of PIPs

Table 6 shows the impact in moving from an I-O based model to a CGE by endogenizing consumption. When a PIP spending shock of 1 per cent of GDP occurs, demand for intermediates, both domestic and imported, rises. Employment rises as the construction sector expands to meet this demand. As a result, incomes of workers increase and so too does consumption. This has an additional multiplier effect on output and employment in the same fashion as described in the closed Leontief model, albeit more realistically due to the use of the LES.

Otherwise there is a marked similarity between the two models. Observe that non-competitive behavior causes the real wage to fall and employment to rise in both. In the I-O model there is no feedback from consumption and employment only rises between 1.0 per cent and 1.36 per cent, as computed from table 3. With consumption adjusting to income, total employment increases by from 2.4 to 3.0 per cent relative to the base.[29] This additional demand due to the endogeneity of consumption increases overall demand and therefore the industrial

[29] Note that the income multiplier, which is not measured as a per cent, varies from 2.5 to 2.1 as the mark-up elasticity rises. This is common for a Keynesian model of this sort. To get a multiplier of 1 or even negative one would have to assume some level of crowding out of investment demand that the PIP caused; the table shows how this might occur as the elasticity of the mark-up rises, albeit to unrealistically high levels.

Table 6: Response to a dam expenditure of 1 per cent of GDP in full CGE with LES

	Base	Response			
Mark-up elasticity[1]					
	0	***0***	***0.20***	***0.50***	***0.80***
Price					
Ag	1	1	1	1	1
Ind	1	1	1.0026	1.0075	1.0143
Value added	118.0	120.9	120.8	120.7	120.5
Ag	48.0	48.7	48.7	48.6	48.5
Ind	70	72.2	72.2	72.1	72.0
Labour demand	72.00	73.76	73.83	73.97	74.15
Ag	300	30.44	30.41	30.37	30.31
Ind	42.00	43.32	43.42	43.60	43.85
CPI	1.0000	1.0000	1.0015	1.0043	1.0082
Consumption	70	71.7	71.7	71.6	71.5
Ag	30	30.7	30.7	30.7	30.7
Ind	40	41.0	40.9	40.9	40.8
Real wage[1]					
Ag	1	1	0.999	0.996	0.992
Ind	1	1	0.999	0.996	0.992

[1] Industrial price response to output by elasticity. Nominal wage deflated by consumer price index (CPI) using consumption weights.
Source: Authors' computations.

price, according to the elasticity of the mark-up. The result is a more vigorous fall in the real wage due to the upward slope of the supply curve. Consequently real wages fall and employment increases. Note that agricultural employment actually falls in the I-O model when the τ elasticity is 0.8 but does not fall below the base level until the τ elasticity rises to 1.5 in the CGE.

The higher relative price of industry draws more employment out of the agricultural sector in the CGE relative to the I-O model. In the I-O model the real wage cannot fall since prices and wages are fixed.[30]

So which is better? One unrealistic feature of the I-O model is that workers maintain their consumption in the onslaught of higher prices. This can only mean that their savings fall. Since savings can be at or near zero in many cases, it is probably better to use the consumption driven CGE model to estimate employment effects because it is more realistic.

The CGE also brings benefits in the government and foreign accounts. There one is able to see quickly how both government and foreign savings respond to a PIP shock. Since output and incomes rise, it follows that tax receipts improve. On the public sector current account (not including the PIP) government savings rise. The public sector borrowing requirement (PSBR), however, increases with cost of the PIP and here is where some crowding out may occur.

Imports are another matter, but can be handled in a similar way. Table 4 show that imports are zero, which implies that the exports are net of competitive imports. One way to incorporate imports is to determine total consumption and then split it into domestically sourced and imported components. The split can be sensitive to the real exchange rate, ep^*/p, where p is the GDP deflator and p^* is an index of foreign prices. This is the Armington assumption, in essence, and it can be devastating to short-run multipliers. If the stimulus due to the PIP leaks abroad, there could be little or no employment growth, although complete leakage is probably unrealistic for most countries. PIP projects are less likely to wash out in this way, since they involve significant domestic labour and little (but not zero) imported equipment.

4.7. Informal sector

In principle the informal sector is counted, like any other, in the national income and product accounts. Gibson and Flaherty (2016) develop the concepts of “juridical” and “structural” informality to give the informal sector economic content rather than defaulting to a legal framework for its definition. The same is true for the so-called “subsistence sector”, where subsistence refers to the biological minima that operators of rudimentary productive processes require. The notion of structural informality developed in Gibson and Flaherty

[30] In having just one nominal wage for all unskilled labour, the model effectively assumes homogenous labour and perfect labour mobility. In reality, better workers get higher wages when there is a local expansion of demand for labour. Over time, this attracts workers from other sectors who are less well remunerated, who then bid down wages. How long this process takes is usually not specified in models, but should be. Note that the same competitive process unfolds with capital. Once the wage falls, because of the competitive pressure from other sectors, the rate of profit increases. This, again, attracts competition, but this time from owners of capital in other sectors. Eventually a common wage and rate of profit is established, but significantly more detailed and disaggregated models, agent-based models for example, are required to show how this process works its way out.

(2016) comprises both informal and subsistence economies. The key definition is that informal/subsistence proprietors operate "defective" production processes, ones that do not return a market rate of profit when labour a market wage. It follows that formal sector firms will *not* operate these processes in equilibrium and if they are observed to exist, it must be that informal operators have no formal-sector alternatives.

While the marginal contribution of informal or subsistence sectors is therefore relatively small, the average contribution can be quite large. Herrera et al. (2012), note, for example, that with respect to urban non-agricultural employment, the informal sector accounts for 70-80 per cent in Sub-Saharan African cities, to 40-60 per cent in Latin America and South Asia. In Rwanda, for another example, 70 per cent of the agricultural sector produces for subsistence and 88 per cent of the 123,000 small and medium size enterprises are juridically informal, paying less than 2 per cent of tax revenue in 2009 (Sennoga et al., 2011).

Detailed instructions for how one might include the informal sector in the models described above are complex and well beyond the scope of this paper. The reader will have to be content with a few, summary, observations. First, the informal sector must necessarily be modeled by way of *alternative processes*, mentioned above in the context of the road paving and construction technologies. In this case, however, both formal and informal processes co-exist in the equilibrium configuration of the model. Why is, again, the cheapest process not selected by the market to dominate? The answer is elaborated in Gibson and Kelley (1994) but can be summarized briefly by noting that the output of the informal processes is limited by the quantity of labour in the informal sector. The second assumption is that the price of the output produced by the informal sector adjusts to that of the formal sector (taking into account any differences in quality) so that the informal mark-up becomes an endogenous variable. This fact has profound consequences for the prosperity of informals. There is no guarantee, for example, that if labour were compensated at the market rate, the rate of return on the process might not turn *negative*. In this case, no formal sector firm would choose to operate the process. Because informals have no other option, however, they must. As the formal sector expands, the labour constraint (the full employment assumption mentioned previously) implies that the number of informals contracts.

4.8. Data requirements

The reader will be excused for supposing that the data requirements for macro models of the sort described above are so overwhelming that quantitative analysis of this sort would be out of reach for most developing economies. As noted, however, economic theory robustly supplies coherency assumptions to fill the gaps where data goes missing. Again, it becomes the structure rather than the data that is given the preponderate voice in the analysis. Nonetheless, it is possible to outline how even rudimentary data can be cobbled together to get some version of "homegrown" models underway.[31]

Note that the SAM is an amalgam of four different and often disparate sources of information.

[31] See Gibson (2008) for additional details. Also see Ernst et al. (2015) for a more specific discussion of the data requirements for building I-O and SAMs.

The first is the national income and product accounts, NIPA, from which the first block of rows in the SAM is constructed. Sectoral proportions often come from the manufacturing census, but agriculture is tougher to estimate properly. Fortunately, methods exist that enforce bi-proportional consistency, on both rows and columns of the SAM, that are often used in their construction. These RAS methods are beyond the scope of the present paper but are well known and widely used.

The second source of information is household surveys that describe the income and expenditure of consumers. These surveys must be scaled to the NIPA data for consistency and again RAS methods are usually necessary.[32] The check on the overall health of the resulting SAM is provided by the savings rates of various income classes that make up the size distribution of income. They must ascend with income and reside in an appropriate range and scale to total household savings. There is some art involved here, but the final product can be checked in numerous ways–including the Gini coefficient–for consistency.

The third component is the government accounts, usually supplied by the ministry of finance. Here the structure of public sector investment expenditure can be estimated as well government current expenditure on goods and services. Government employment is also provided but must not be double counted, if state-owned enterprises are already counted in the economic census.

The last component is the balance of payments. The integration of this data poses particularly thorny questions given that they are typically published in US dollars and therefore must be converted to LCUs. Balance of payments data can be used to check the consistency of estimates of imports and exports, as well as the level of foreign transfers and interest payments.

The hidden assumption here is that the SAM is built from an existing I-O matrix. This may pose a problem for exceptionally poor countries, but most have at least one I-O matrix and many collect this information every five years. If the matrix is out of date, RAS methods can be used to update the base matrix to currently published row and column totals from economic censuses. The resulting SAM is then balanced and used for the calibration of the model. The process is shaky, admittedly, but not without intrinsic value. As data quality diminishes, detailed and accurate forecasts become more difficult, but the model can still be of great value in instructing policy-makers on the nature of the linkages in the macroeconomy.

In contrast, the data requirements for RCTs are more demanding in depth than breadth. As noted, they may be prohibitively expensive, unethical/politically objectionable, impractical, or even impossible to carry out. As discussed above, the elimination of selection bias is critical to a valid assessment of the treatment effect of policy. The survey design and construction of the control versus the treated population bear the burden of generating reliable data. Depending upon the characteristics of the population available for the RCT, rigorous separation of treatment effects from variations within the population may be difficult for policy-makers to understand. Whether the data requirements of the sector or country level macro models or the RCTs pose more of a constraint in developing countries is not a question that can be answered easily in the abstract. It can only be said that while the I-O and SAM

[32]RAS is not an acronym but are the symbolic names of adjustment matrices in the RAS method (Bacharach, 1970).

techniques have internal criteria for consistency, there is no analog in RCTs. The survey design performs this function, but without an internal check on the existence of selection bias.

5. Dynamic Models

Dynamic SAMs have been used by the ILO as a tool for employment impact analysis for roughly the last decade (Alarcón et al., 2011). These approaches offer the great benefit of simplicity and are by-and-large unconstrained by theory. As such, dynamic SAMs are essentially a *data base* rather than a model per se. The great advantage of theory-free observation has been publicized recently by the award of the 2015 Nobel Prize in Economics to Angus Deaton, a proponent of "letting the data speak for itself." Dynamic SAMs take another step in that direction, by omitting theory almost entirely, thereby generating a path along which each point is expanded to a full social accounting matrix.

Another way to envision the difference between the methodological approach advanced here and that of the dynamic SAM literature is to consider a static, one-period SAM. From a statistical perspective, a static SAM provides *cross sectional* data since there is no time element present. It follows that dynamic SAMs present a consistent set of *panel* data, also referred to as pooled cross-sectional and time series data. Central tendencies of panel data can be extracted by way of the generalized method of moments, again the subject of a recent Nobel. These models vary in their intensity and veracity and currently populate the front lines of vigorous debate with the *randomistas*, those who maintain that the RCT methods discussed in detail above are the gold standard of scientific inquiry.

Consider a NIPA data stream for a given time period for a given country. DySAM techniques show how each scalar in this sequence can be expanded to a matrix, the static-SAM snapshot of that period. In the extreme case, no consumption function need be employed since the actual data for consumption is recorded, just as it appears in the NIPA and corroborating household surveys.

Stepping back from the theoretically agnostic perspective embodied in the DySAM literature, one can capture a dynamic sequence by way of structure, again much in the same way that structure is imposed on a static SAM to enable comparative static (multiplier) analysis. What follows is an explanation of just how this might unfold in a simple case of the analysis of a PIP in the framework of a reasonably realistic dynamic CGE. This is not to suggest that the method discussed here should replace the DySAM methodology, only supplement it.

Dynamic stochastic general equilibrium models (DSGEs) have earned a reputation for notable departures from the reality of developed countries, not to mention developing countries. It is not hard to see why. The consumption functions used in static CGEs can be linked to utility functions by way of the usual methods of optimization subject to constraints. While it is one thing to propose that agents optimize in a given period of time, it is quite another to say that they successfully optimize over time. The degree of uncertainty about the future prohibits simple and clear solutions and if the CGE modeler chooses to back solve the system under the assumption that agents will on average pick the correct dynamic path of the economy, and from that path deduce their current period inducement to invest, credulity is stretched to its breaking point.

Keynesian motifs provide an alternative when thinking about how to model the investment function in static or dynamic CGEs. Simple approaches work well when the inducement to invest is linked to current capacity utilization with a term to reflect crowding-in/out from PIPs. This approach can and has been criticized for building desired conclusions into the framework, but at least it is capable of showing what might unfold at different degrees of intensity of crowding in (or out) if the *raison d'être* of PIP is achieved, that is to promote private sector investment. While it is true that the model will come to reflect the imposed Keynesian structure rather than just the data itself, it can be useful for "what if" counterfactuals.

Dynamic paths, whether determined by the DySAM or the dynamic CGE methodology, take into explicit account the time required to adjust the factors of production to their best combination given factor prices. The fundamental assumption driving the analysis of the short-run above is that the capital stock is fixed while labour can be hired and fired relatively quickly. This differential treatment is characteristic of dynamic CGEs.

All dynamic models can be thought of as having both "state" and "jump" variables. At any given point in time, as described for example by a social accounting matrix, the jump variables come into equilibrium. The equilibrium takes the state variable as given for the period in question and then takes account of the levels of the jump variables in equilibrium insofar as they have an impact on the time-path of the state variables.

A stylized sequence of steps under which simulations of this nature are typically constructed is

1. start with a calibrated series of dynamic SAM/CGEs that track recent data for the economy reasonably well.

2. construct a counterfactual that has a desired shock, in this case a public investment project of 1 per cent of GDP.

3. after confirming that the model solves properly, check that no feasibility constraints are violated.

4. ask which markets have cleared and which have not. For markets that have not cleared, examine the reasons why and change the adjustment mechanism if appropriate. For example: do capacity utilization rates exceed one? If so then implement corrective measures, such as a more rapid rate of capital accumulation, technical change and growth in the labour force. One way to slow down the rate of growth of GDP, and thus capacity utilization, is to speed up the import response.

   Overly responsive models usually have insufficiently substitution, either in consumption or production and in the latter, either intermediates or factors of production. Their linear structure produces multipliers that are unrealistically large. In general," it is always easy to build in substitution with a function of the form:

$$Z_t = (\frac{\zeta^t}{\zeta_0})^{\epsilon} \tag{16}$$

where Z_t is the response and ζ_t is the driver. The elasticity of the response to the driver is ϵ. An example is the proportion of income spent on food. In the current model, this share is fixed by α but there is no reason why α cannot be considered a state variable that adjusts with either income or price (or both). If there is information on Engel elasticities, the driver might be $\zeta = Y$. Thus, as income increases relative to the base SAM, the budget share spent on food decreases. Alternatively, if the real exchange rate is the driver and it appreciates, the share of imports–the response–usually rises. This is nothing more than an *Armington* function and is easily implemented in computational models.

5. Ask if the model is on a path converging to a steady state or whether it is on a random walk.

5.1. Simulating a PIP with constant wages and prices

In the CGE model described above, the capital stock is a state variable, taken as given for the period of the model. On the other hand, the SAM has a level of investment that has an impact on the levels of the capital stock in the next period.

One simple model of the level of investment by *destination* is that it be given by the accelerator

$$I_j = (i_0 + i_{1j}u_{jt})K_{jt-1} \quad j = 1, 2 \tag{17}$$

where i_{j0} is a constant and is sometimes referred to as an "animal spirits" term. Note that it may be linked through more algebra to the PIPs with different degrees of crowding in/out.[33] Here i_{1j} is the accelerator and K_{jt-1} is capital in the previous period for sector j, either agriculture or industry. The utilization of capital in period t, u_{jt} depends on

$$u_{jt} = Y_{jt}/Q_{jt}$$

where income Y_t is given by the level of *aggregate demand* or

$$Y_{jt} = C_{ji} + I_{ji} + G_{ji} + E_{ji} - M_{ji} \tag{18}$$

where C_{ji} is consumption, I_{ji} is investment by origin (demand for goods and services), G_{ji} is government spending on goods and services, E_{ji} is exports and M_{ji} is imports. Capacity, Q_{jt}, is now given by the Cobb-Douglas

$$Q_{jt} = \mathcal{A}_{jt}K^{\beta_{jt}}L^{1-\beta_{jt}}$$

where $\mathcal{A}_{jt}$ is an arbitrary constant, as before, K_{jt} is the available capital stock and β_{jt} is the share of the return to capital in total output. Employment, L, is given by the marginal

[33] Despite the hoopla, the previous paragraphs, this is not done here for simplicity and manageability.

Table 7: Basic parameter settings

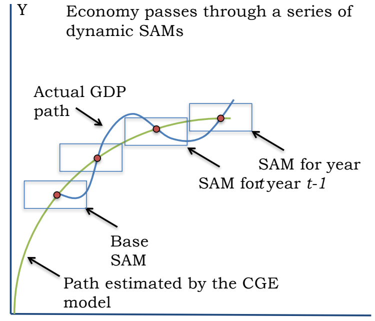
	Sim 1		Sim 2	
	Ag (%)	Ind (%)	Ag (%)	Ind (%)
Depreciation[1] (δ) rate	5.0	5.0	5.0	5.0
Autonomous investment[1] (i_0) growth	2.0	2.0	2.0	2.0
Discount rate[1]	5.0	5.0	5.0	5.0
Government spending growth[1]	1.0	1.0	1.0	1.0
Net exports growth[1]	0	0	0	0.5[3]
Rate of return on capital[2]	17.1	18.6	17.1	18.6
Wage (nominal) growth	0	0	1.0[3]	1.0[3]
Mark-up (τ) growth	0	0	0	0.1[3]
Labour force growth	1.0	1.0	1.0	1.5[3]
Technical change ($\mathcal{A}$) growth	0	0	0	0.5[3]

Parameters *not* calibrated from SAM. 2. From the base SAM. See footnote 19 on page 27. 3. Time periods 5-11 only.
Source: Authors' computations

productivity conditions in equation 15 above. Nominal value added in that equation can then be written as $v_{jt} = u_{jt}p_{jt}Q_{jt}$. Thus, as capacity utilization rises, demand for labour also increases in proportion, so long as prices and wages remain constant. Introducing two sectors increases the complexity of the model by a significant factor. It is not only necessary to know a component of aggregate demand, say G, but also how that scalar value is split up into two components of a vector, G_1 spent on agriculture and G_2 spent on industry. This is true for all components of aggregate demand. Here it is assumed that the internal proportions of the base SAM remain in force, absent information to the contrary. Certainly the fixed proportions assumption is crude, but for the moment it is the most efficient way to proceed.

It is important to keep in mind that while investment is motivated by capacity utilization and animal spirits on the destination side, there is nothing to motivate splitting total investment into investment demand for goods produced by the agricultural sector versus those produced by industry on the origin side other than the structure of the initial data. These proportions depend on the nature of the capital good itself and are held fixed in the model to follow.

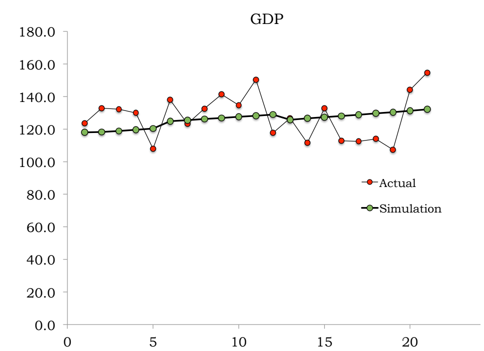
Figure 6: A sequence of SAMs along a dynamic path, joined by dynamic CGE estimates



Generating the dynamic CGE is now a sequential process. The first step is to collect data over a relatively recent historical period to which the dynamic model can be calibrated. Once calibrated the model should closely follow the data and counterfactual paths can be calculated and compared with the actual. The question becomes: if the country had introduced a PIP during some range of years in the model, how would have employment changed? What would have happened to wages? How would the discounted stream of consumption be affected? All these questions can be analyzed using a dynamic CGE calibrated to historical data.

Figure 7 shows the results of the calibration process. The fit is achieved as a result of setting exogenous growth rates for the key exogenous parameters of the model, such as the parameters of the investment function identified above, the response to capacity utilization, the consumption parameters, government spending and exports.

Figure 7: Calibrated and actual GDP



In the exercise to follow, the model produces a sequence of SAMs. If SAMs are available for some subset of the years, then the parameters can be adjusted to account for whatever structural change the economy has undergone in the interim. As shown in figure 6, the model passes through the existing SAM and then interpolates new SAMs for the years in between.

In the two simulations to follow, assume that the project takes 7 years to complete and is the equivalent of 1 per cent of base-year GDP spent on investment by the public sector in each of the 7 years.[34] The results of the first simulation with fixed wages and prices, are shown in figure 8. Employment rises in period 5 and continues at an elevated level until period 12. The effect is more pronounced for the industrial sector that supplies the capital goods, but a smaller indirect effect of the PIP on agricultural sector employment can also been see in the figure. Table 8 shows more precisely the effect of introducing a PIP in time period $t = 5$.[35].

It would be a simple matter to construct a SAM for each of the 20 simulated years beyond the base SAM shown above in figure 4. This sequence of SAMs would correspond to what is shown in figure 6. The reasoning should now be self-evident. In each year the model calculates a general equilibrium, which implies an income-expenditure balance, in that the sum of savings is equal to the sum of investment.

The first column of table 8 shows the employment in agriculture. How much labour is hired per unit of output (demand) depends on the real wage, as in equation 15 above. In this simulation neither prices nor wages are changing, so employment is proportional to the growth in aggregate demand. In the first period of the PIP, employment growth increases in column 1 to 1.8 per cent in agriculture and in column 2 to approximately 3.5 per cent in

[34]Download the Excel file here.
[35]The investment *shock* is shown in table 8, column 12.

industry. This kick up in employment growth due to the PIP lasts for the duration of the project. In the years after the completion of the PIP, some employment growth (0.1-0.2 per cent) lingers. It can be seen in the last row of table 8 that the average rate of growth of employment over the entire period is 0.55 per cent higher for agriculture and 0.72 per cent higher for industry due to the PIP.

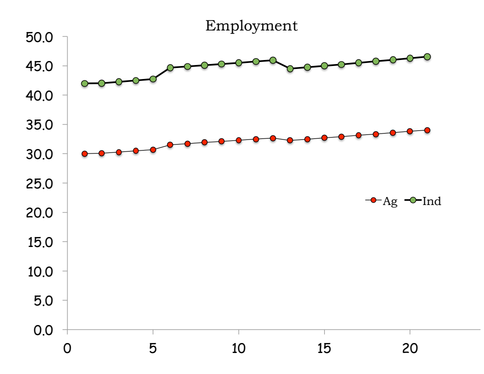
The next two columns measure the impact on the labour market, measured as U_t, the unemployment rate or the percentage of the labour force that is unemployed given an exogenous growth in the labour force, $\bar{L}_t$ shown in table 7. Not surprisingly the table shows a decrease in the years of the PIP, roughly twice as large for industry as agriculture. This number is somewhat arbitrary given the problem surrounding the measurement of the unemployment rate, but it can be taken as an index of the excess demand pressure put on the labour market by the PIP. Note that during the years of the project the unemployment measure goes negative, more so for the industrial sector where the increase in demand is concentrated. Excess demand for labour, presumably, would have to be satisfied by in-migration. To what extent the in-migration is feasible and to what extent the inflow would affect the path of nominal wages is something best determined by local expertise rather than a one-size-fits-all equation from the model builder.

Both agricultural and industrial gross output in columns 5 and 6 table 8 increase by the same rate as employment, due to the direct link between output and employment growth in the model with fixed prices and wages. Employment in this model is clearly demand driven.

Simulated GDP is computed next in column 7 of table 8 followed by the distribution of nominal value added across the two sectors in columns 8 and 9. A GDP deflator is also shown in column 10, but in this simulation, wages and prices are fixed by assumption so the deflator remains at 100.

Real consumption of the two goods is computed using the LES as described above and shown in columns 10 and 11. Since relative prices are fixed there is no opportunity for consumers to respond to relative price changes and therefore the LES does not bias the result in any way.[36] It is an easy matter to select a discount rate to measure the net present value of the project insofar as it is reflected in higher levels of consumption. At 5 per cent, the net present value of consumption rises from 949 in the base run with no PIP (not shown) to 959 or 1 per cent. The effect is small, but the dam is not assumed to have any spillover effect on production, other than through intermediates and consumption. This may well underestimate the effect of the dam if it generates electricity, provides a recreational area or any other service.

Figure 8: Employment as a response to a PIP of one per cent of GDP



[36]The AIDS demand system might be better when relative prices change, since it would allow more substitution as noted above.

Investment is driven by capacity utilization and an "animal spirits" term as described in equation 17 above. Investment is computed by destination, since this is its causal driver. Investment in columns 13 and 14, however, is shown by origin, already distributed across the two sectors with the fixed sector shares referred to above. There is no explicit crowding-in/out term as noted above.

Government current spending (excluding investment in the PIP) is calibrated to an exogenous growth rate of one per cent as shown in table 7, while the growth in *net* exports is zero. This does not imply the neither exports nor imports change, but only that the rate of growth is the same for both. These are all arbitrary choices, but they enable the calculation of a *counterfactual* simulation undertaken here.[37]

The capital stock adjustment equation imposes so-called "stock-flow consistency" on the model. The capital stock in period t, K_{jt} depends on the capital stock in the previous period, K_{jt-1}, less depreciation δ, plus investment by destination in the previous period. It can be written

$$K_{jt} = K_{jt-1}(1-\delta) + I_{t-1}$$

where δ is given in table 7. The stock-flow equation connects the time periods by way of a path for the two state variables, K_1 and K_2, shown in the columns 15 and 16 of table 8.

With an exogenous estimate of the growth of the labour force, $\bar{L_t}$ and exogenous technical change, $\mathcal{A}$, in equation 5.1, one can compute the level of potential or capacity output, Q_{jt}. When this supply-side measure is compared to the demand side of the economy, the rate of capacity utilization can be expressed, $u_{jt} = Y_{jt}/Q_{jt}$. The (absolute) difference between the base and simulation is shown in columns 17 and 18 of table 8.

[37] In the second simulation, imports are allowed to grow slightly faster than exports during the PIP period and, as shall be seen, this reduces the impact of the PIP on domestic employment growth. See the discussion of table 9 below.

Table 8: Sim 1: Response to a dam expenditure of 1 per cent of GDP Fixed prices and wages and no growth in imports (change from base)

Time[1]	L_1	L_2	U_1	U_2	X_1	X_2	GDP	Y_1	Y_2	C_1	C_2	Shock	I_1	I_2	K_1	K_2	u_1	u_2
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*17*	*18*
	%[2]	%	Δ	Δ	%	%	%	%	%	%	%	Δ	%	%	%	%	Δ	Δ
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	1.8	3.6	-1.8	-3.5	1.8	3.6	2.8	1.8	3.6	2.8	2.8	1.18	1.8	16.4	0.0	0.0	0.02	0.04
6	1.8	3.6	-1.8	-3.5	1.8	3.6	2.8	1.8	3.6	2.8	2.8	1.18	1.8	16.5	0.1	0.1	0.02	0.03
7	1.8	3.5	-1.8	-3.5	1.8	3.5	2.8	1.8	3.5	2.8	2.8	1.18	1.9	16.6	0.1	0.2	0.02	0.03
8	1.8	3.5	-1.8	-3.5	1.8	3.5	2.8	1.8	3.5	2.8	2.8	1.18	2.0	16.6	0.1	0.3	0.02	0.03
9	1.8	3.5	-1.9	-3.5	1.8	3.5	2.8	1.8	3.5	2.8	2.8	1.18	2.1	16.7	0.2	0.5	0.02	0.03
10	1.8	3.5	-1.9	-3.5	1.8	3.5	2.8	1.8	3.5	2.8	2.8	1.18	2.1	16.7	0.2	0.6	0.02	0.03
11	1.8	3.5	-1.9	-3.5	1.8	3.5	2.8	1.8	3.5	2.8	2.8	1.18	2.2	16.8	0.3	0.7	0.02	0.03
12	0.1	0.2	-0.13	-0.16	0.1	0.2	0.1	0.1	0.2	0	0.1	0	0.6	0.6	0.3	0.8	0	0
13	0.1	0.2	-0.12	-0.16	0.1	0.2	0.1	0.1	0.2	0	0.1	0	0.6	0.6	0.3	0.8	0	0
14	0.1	0.2	-0.12	-0.16	0.1	0.2	0.1	0.1	0.2	0	0.1	0	0.6	0.6	0.3	0.8	0	0
15	0.1	0.2	-0.12	-0.16	0.1	0.2	0.1	0.1	0.2	0	0.1	0	0.5	0.5	0.3	0.8	0	0
16	0.1	0.1	-0.12	-0.16	0.1	0.1	0.1	0.1	0.1	0	0.1	0	0.5	0.5	0.3	0.8	0	0
17	0.1	0.1	-0.12	-0.15	0.1	0.1	0.1	0.1	0.1	0	0.1	0	0.5	0.5	0.3	0.8	0	0
18	0.1	0.1	-0.12	-0.15	0.1	0.1	0.1	0.1	0.1	0	0.1	0	0.5	0.5	0.3	0.8	0	0
19	0.1	0.1	-0.12	-0.15	0.1	0.1	0.1	0.1	0.1	0	0.1	0	0.5	0.5	0.3	0.8	0	0
20	0.1	0.1	-0.12	-0.15	0.1	0.1	0.1	0.1	0.1	0	0.1	0	0.5	0.5	0.3	0.7	0	0
Growth	0.0055	0.0072	-0.09	-0.16	0.00	0.01	0.0065	0.01	0.01	0	0.01	0	0.03	0.03	0.02	0.05	0	-0.01

L = labour demand, U = unemployment, X = real gross output, Y = nominal income, C = real consumption, I = real investment, K = real capital stock, u = capacity utilization.

1. Models variables with no change are not shown. Columns with percentage signs are per cent change from base. 2. Columns with Δs are absolute changes.
3. Difference between the growth rates of the simulation and base for the entire period, 0-20.

Source: Authors' computations .

The shaded regions of columns 13 and 14 of table 8 show how investment responds to PIP shock. The shock is additive, simply increasing the total amount of investment demand for sector 2. The shock is considered to be a budget item of government, in this case, and does not directly affect the investment plans of firms in either sector. The shock does, of course, raise total aggregate demand, and with it, capacity utilization in each sector according to equation 17 above. In this way the shock acts to indirectly increase the pace of private capital accumulation in the economy.

Columns 17 and 18 of table 8 confirm that capacity utilization does slightly rise in both sectors. For industry, the column includes the effect of the exogenous increase in government investment due to the PIP. There is also an increase in u_1 for agriculture, even given the assumption that agriculture *supplies no capital goods*. The rise in the utilization of agricultural capital is brought about by the increased demand for agricultural goods as an *indirect* effect of the PIP. Columns 15 and 16 of the table show that the capital stock grows considerably more rapidly in the industrial sector than in agriculture. This rise mitigates the increase in capacity utilization, of course, as seen in equation 5.1 above.

5.2. Simulating a PIP with flexible wages and prices

Until now, prices and wages remain fixed and unrealistically so. Dynamic CGE models open up a wide range of possibilities, however, and the ability to model complex and subtle adjustment mechanisms is boundless. One need only be armed with some knowledge of how the economy actually works.

In this second simulation, the nominal wage increases by one per cent during the PIP period, as seen in table 7, and the mark-up in industry increases by 0.1 per cent. As in the first simulation above, the model introduces a PIP that increases government investment demand during a subset of the years of the simulation, time periods 5-11. Figure 9 shows the pattern of prices that emerges from these assumptions. These parameter settings are arbitrary, but do serve to illustrate how a PIP of sufficient size might affect a developing economy. Table 9 gives the results of the second simulation with the PIP period shown in the shaded region.

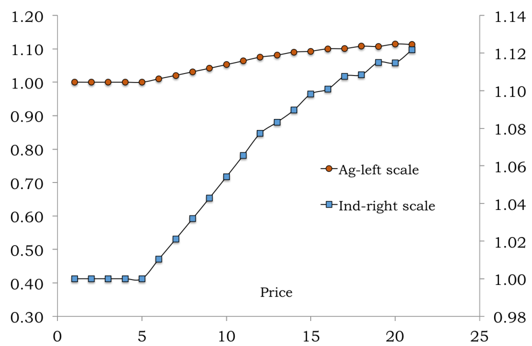
Employment depends on the marginal product, one period lagged. Were the marginal product not lagged, the price equation (11) above would not provide an independent equation in the system (due to the adding-up property of the Cobb-Douglas). Moreover, lagging introduces some interesting, and dare say realistic, behavior to the model. At the moment the marginal product blueprint of the previous period is adopted, a new labour coefficient becomes operative in the determination of price.[38] Since the movement of nominal wages is independent of this process, a real wage emerges endogenously. The real wage then drives the new selection of technique (capital-labour ratio), more capital intensive if it rises, and more labour intensive if it falls.

The introduction of the PIP increases demand for both sectors, through the backward linkages of intermediate demand in the I-O matrix, as in the first simulation. As a result, labour

[38]In static models, this lack of independence does not pose a problem, since the labour coefficient is calibrated to the base SAM.

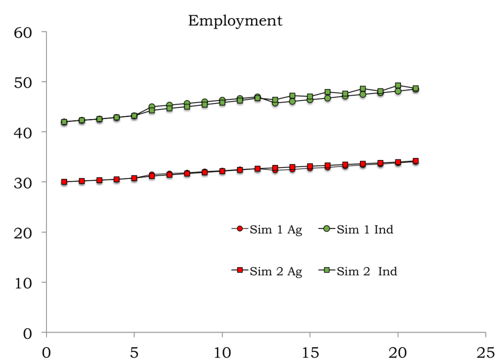
demand increases as shown in columns 1 and 2 in table 9. The employment response is somewhat more robust compared to the fixed-price simulation shown in figure 10. This does not imply that flexible prices will always generate more employment, but this simulation shows that it may well turn out that way.

Figure 9: Prices in simulation 2



Columns 5 and 6 of table 9 show that the rise in prices does in fact cause a small contraction in output in the agricultural sector, a possibility alluded to in the above discussion that has now become real. Recall why this happens. If prices rise, higher input costs reduce value added in agriculture. The income does not disappear, but is channeled away from agriculture to profits (rather than wages) in the industrial sector. In the static model above, this reduced output because demand was lower.[39] The same happens to agriculture in the dynamic model, but only during the PIP period. As seen in figure 11, GDP increases slightly faster over the period as a whole (0.2 per cent) with flexible wages and prices. This is because of the fall in the real wage, as shown in figure 12 and highlights the fact that better jobs trade off with more jobs. What the simulation shows is how long it takes to provide formal sector employment for most of the labour force.

Figure 10: Employment in the two simulations



This trade-off is again visible in the columns for nominal value added (8 and 9) as well as consumption in columns 10 and 11. Further evidence of the trade-off between current and future well being is offered in the rate at which capital accumulates in the two simulations. In the first, the capital stock contracts in agriculture and only grows by 0.3 per cent in industry; in the second, the contraction in agriculture is still present, but the growth in industrial capital is nearly double.[40]

[39]The loss in labour income was not made-up for by an increase in investment, so total demand fell. Here, however, higher profits lead to faster growth.

[40]Absolute values are not shown. In fact agriculture's capital stock is shrinking.

Figure 11: GDP in the two simulations

Inflation rises from 0 in the first experiment–by assumption of no wage or price response to the PIP–to 0.5 per cent in the second, as seen in the last row of column 12 in table 9.[41] That real growth is primarily demand driven is evident in columns 18 and 19; despite the faster accumulation of capital, utilization is substantially higher in the second simulation relative to the first. Imports also rise in the second simulation by an assumed 50 per cent of the investment shock.[42] Even though it is a large fraction of the shock, the rise in imports is not a game-changer. It only reduces GDP by a negligible amount. How much imports are likely to increase as result of the PIP is again a matter for local expertise and cannot easily be determined a priori.

[41]The reader should not be surprised by how small these numbers are since the shock itself was only 1 per cent of GDP.

[42]This arbitrary number may be regarded as too high for some developing countries but not high enough for others. The reader is invited to download the spreadsheet for the model and change the percentage as desired.

Table 9: Sim 2: Response to a dam expenditure of 1 per cent of GDP with variable prices and wages and growth in imports (change from base)

Time[1]	L_1	L_2	U_1	U_2	X_1	X_2	GDP	Y_1	Y_2	C_1	C_2	Shock	I_1	I_2	K_1	K_2	u_1	u_2
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*17*	*18*
	%[2]	%	Δ	Δ	%	%	%	%	%	%	%	Δ	%	%	%	%	Δ	Δ
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	1.1	2.1	-1.2	-5.6	-0.1	2.1	1.7	2.2	3.1	1.7	1.7	1.0	2.1	16.9	0.0	0.0	0.01	0.03
6	1.5	2.6	-1.5	-9.9	-0.1	2.5	2.1	3.5	4.6	2.1	2.1	2.0	3.8	18.8	0.1	0.1	0.01	0.05
7	1.9	3.1	-1.9	-14.3	-0.1	3.0	2.5	5.0	6.2	2.5	2.4	3.1	5.7	20.8	0.2	0.4	0.02	0.08
8	2.3	3.6	-2.3	-19.0	-0.1	3.5	3.0	6.4	7.8	2.9	2.8	4.1	7.7	22.9	0.3	0.7	0.02	0.10
9	2.7	4.1	-2.7	-24.0	-0.1	4.0	3.4	7.9	9.4	3.3	3.3	5.2	9.7	25.2	0.5	1.2	0.02	0.12
10	3.1	4.6	-3.2	-29.2	-0.1	4.5	3.9	9.5	11.1	3.7	3.7	6.3	11.9	27.5	0.7	1.8	0.03	0.14
11	3.6	5.2	-3.7	-34.7	-0.1	5.0	4.3	11.0	12.8	4.2	4.1	7.5	14.2	29.9	0.9	2.4	0.03	0.15
12	3.5	3.9	-3.6	-33.5	0	3.6	3.3	11.0	12.0	3.1	3.1	0	14.8	14.8	1.2	3.2	0	0.1
13	3.4	5.1	-3.5	-34.8	0	4.3	3.9	12.7	13.8	4.0	4.0	0	16.4	16.4	1.5	4.0	0	0.2
14	3.3	3.9	-3.5	-33.8	0	3.6	3.3	12.1	13.1	2.9	2.7	0	16.6	16.6	1.9	4.9	0	0.1
15	3.2	5.2	-3.4	-35.2	0	4.6	4.2	13.9	15.1	4.1	4.1	0	18.3	18.3	2.2	5.7	0	0.2
16	3.2	3.8	-3.3	-33.8	0	3.8	3.4	13.0	14.1	3.0	2.8	0	18.3	18.3	2.5	6.5	0	0.1
17	3.1	5.3	-3.2	-35.5	0	5.0	4.5	15.0	16.3	4.5	4.5	0	20.3	20.3	2.9	7.4	0	0.1
18	3.0	3.6	-3.1	-33.8	0	4.0	3.6	13.8	15.0	3.2	2.9	0	20.1	20.1	3.3	8.3	0	0.1
19	2.9	5.3	-3.1	-35.7	0	5.5	4.9	16.1	17.5	4.9	4.9	0	22.2	22.2	3.6	9.2	0	0.1
20	2.8	3.3	-3.0	-33.8	0	4.2	3.9	14.6	15.8	3.4	3.0	0	21.8	21.8	4.0	10.1	0	0.1
Growth	0.1	0.2	-3.8	-12.2	0	0.2	0.191	0.7	0.7	0.5	0.2	0.5	0.0	1.0	1.0	0.0	0	0.0

L = labour demand, U = unemployment, X = real gross output, Y = nominal income, C = real consumption, I = real investment, K = real capital stock, u = capacity utilization.
Notes 1. Models variables with no change are not shown. Columns with percentage signs are per cent change from base. 2. Columns with Δs are absolute changes. 3. Difference between the growth rates of the simulation and base for the entire period, 0-20.

Source: Authors' computations .

Observe that there really cannot be any analysis of inflation in a model without a money supply. The upward pressure on prices in simulation 2 may or may not be validated by expansionary monetary policy. The rise in prices does cause an appreciation of the real exchange rate and drop off of competitiveness in exports, with detrimental effects on the trade deficit and balance of payments. This effect is not included in the model. Indeed, much of the institutional detail highly relevant to the model has been omitted. The assumption that the path of nominal wages is exogenously given provides an obvious example. A rise in the prices of goods, induced by the PIP, will immediately reduce the real wage in both sectors. The reaction on the part of workers is, at this point, unknown and model builders must reference the political economy of the country to which it is calibrated to fill in details here.

Figure 12: Real wage in simulation 2

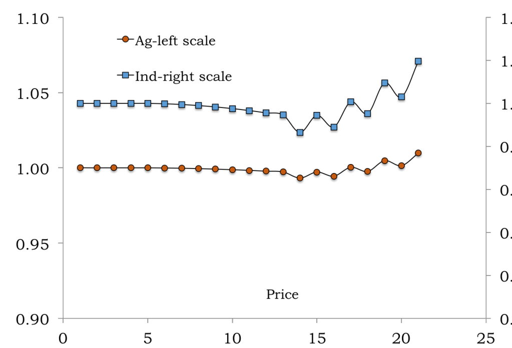


Figure 12 shows the evolution of the real wage in the second simulation. The degree to which the PIP affords additional decent work is unimpressive as most of the gains go to increasing employment. In the first simulation, decent jobs are maintained (constant real wage) by assumption. This captures only the visible tip of an extensive iceberg however, since decent jobs are characterized by better working conditions and many other features. One is confident however, that better working conditions *must come from capital accumulation, foreign or domestic*. Here, simulation 2 shows a clear advantage in that its growth in capital stock is greater. Sacrifices of real income on the part workers have been made, clearly, at the beginning of the simulated path but both higher levels of employment as well as improved working conditions eventually materialize.[43]

Since there is no monetary sector in the model, it is slightly wage-led even with imports. In reality, a rise in the rate of inflation might cause alarm among the monetary authorities and some contraction in the rate of investment, crowding out, could result. The central bank is also involved in how a PIP ultimately affects employment. An aggressive central bank that is bent on maintaining a competitive exchange rate will follow wage and price increases with nominal devaluation in an effort to keep the real exchange rate constant. This can provoke serious opposition however, if importers and multi-lateral investors are big players on the political stage. If much of the capital equipment is imported, the devaluation could slow investment in both sectors as they respond to the PIP. All this is well beyond the scope of this simple introductory treatment, but not beyond the scope of the ability of the model itself to address.

[43]The net present value of consumption for all households rises 2.1 per cent with flexible wages due to the PIP, more than twice as much as in the first simulation.

6. Simulation methods and machine learning

This paper has relied heavily on modern computer simulation methods, but there are recent advances in the field that have not, so far, been mentioned. Work over the last decades in artificial intelligence has provided researchers with new simulation methods that build the macroeconomy directly from atomistic *agents* and is referred to as either agent-based modeling or multi-agent systems (Epstein, 1999). Insofar as there are macroeconomic properties of interest, they arise from the simulation as "emergent properties," properties that are not imposed from above or by the outside observer but rather devolve from large-scale interaction of self-interested electronic entities. Agents need not be self-interested in the sense that they reject reciprocal altruism, but only in that their behavior is purposeful and that they *learn* from interaction with other agents, which improves–or not–their own well-being. In this regard, the methodology admits standard rational dynamic utility maximizing agents as well as agents guided by behavioral heuristics. Only truly random behavior, noise that drives out any signal whatsoever, is ruled out.

These models are only the last step in a decades long odyssey from models that over-rely on their structure rather than the empirical characteristics of their agents. In earlier times in which reliable data describing the behavior of individuals was scarce, structure necessarily played a predominant role. In particular, the representative agent method rose to prominence as a way of integrating the basic principles of optimization into large empirical models. With the rise of massive data structures that increasingly record virtually every aspect of human behavior by way of the internet or direct observation, the era of scarce unreliable data seems to be coming to a close. This is perhaps more true in developed than developing countries, but the electronic societies in which for example, one out every five individuals has a *Facebook* account, will ultimately have serious repercussions for how economic models are built and interpreted.

More startling perhaps is the damage an agent-based perspective does to macroeconomic models, such as those surveyed in this paper. In a profound sense this approach announces the death of the "macro perspective" with surety that comes from the knowledge that all observable macro variables necessarily sum up micro behavior. Getting the macro characteristics of a given social structure right must ultimately mean getting the microeconomic behavior and interaction of the underlying agents right. The *randomistas*, the Poverty Action Lab as a most salient example, play a complementary role here, one that is essential in teasing out what really does and does not matter at the micro-behavior level. Assumptions of hyper-rationality that seek to replace the empirical findings of this group of researchers can all, in principle, be thrown out.

Applications to development economics are, to say the least, in their infancy. Gibson (2012) develops an agent-based model for the effect of trade on the growth of the informal sector. Productive agents can choose to outsource, go off shore or stay local and hire workers from the domestic workforce. The counterpart of each strategy is modeled as the growth or contraction of the informal sector with attendant effects on productivity, decent work and formal employment growth.

From the perspective of the policy establishment, these models surely constitute the wave of the future. As unleashed more than 40 years ago, the rational expectations revolution changed macro modeling fundamentally. Prior models took agents' behavior to be independent of the policy environment. Agents, in fact, are able to forecast the environment and often respond in perverse ways as viewed by policy-makers. Macromodels typically ignored these complications, running the risk of advocating counterproductive or ineffective policies. This "pushing on a string" problem is essentially that the policy lever settings have not only changed the variables but also the parameters that govern the agents' behavior. Only policy that takes into account an accurate model of the individual's response can possibly be causal, in the sense of useful as the basis on which to develop a successful policy intervention.

Developing even a prototype agent-based model of the impact of a PIP on employment is well beyond the scope of this paper, but it is not beyond the scope of current capabilities of economists trained in data science and computational model building. It is perhaps the next step to be taken.

7. Conclusions: Costs and benefits of models of employment impact

What working knowledge and main assumptions allow investigators to analyze employment impacts of public investment projects? First and foremost, a SAM is required as a data base to which some model of the economy must be calibrated. Thereafter, a significant amount of carpentry is required to get the standard CGE approach to fit the local conditions. Bespoke models are not easy to build, but it must be tried in collabouration with local economists who understand the principal mechanisms of adjustment in their economies. A clear and convincing model will have simple, transparent adjustment mechanisms that reflect how the local economy actually functions, rather than "pie-in-the-sky" assumptions about perfect information and unlimited bandwidth required for optimization over an infinite time horizon. This last point is key: all it takes is one unrealistic assumption to ruin an entire model in the eyes of a policymaker.[44]

This paper has shown how one can assess employment impacts of various public investment projects, ranging from the small to a level (one per cent of GDP) that might attain macroeconomic visibility.[45] In all cases, indirect effects of a project are present, so it would be wrong to conclude that a road that has virtually no impact on the national income and product accounts would also have no impact on a neighboring village. Indirect effects not covered by the breadth or depth of an I-O study are notoriously difficult to estimate and work is proceeding on regional IO models, but here it is important to keep in mind that the absence of evidence is *not* evidence of absence (de Vet et al., 2010).

As more data become available, models employing that data can proliferate in both coverage

[44]Informality and subsistence activities present a whole new set of challenges. Now the SAM and attendant model must be "unrealistic" to the extent that the NIPA fail to record the informal activity. This is not, however, an insurmountable barrier and is deserving of further research to add to the relatively underdeveloped literature on the topic that currently exists. See Gibson and Flaherty (2016) and references cited therein.

[45]Here is it clear that partial equilibrium methods, including RCTs, may be more appropriate. As the number of studies build, their results may complement the macroeconomic effort.

and complexity. The perspective of this paper has been that to use someone else's model of the labour market dynamic of your economy is not necessarily worthwhile. In-house construction of models is far more rewarding for both the users and the producers of the models. First, and above all, one need not search for hidden assumptions when building one's own model, since one builds them in along the way. Moreover, homegrown models can incorporate local structural knowledge of how the economy actually works.

The star of this paper in this regard is equation 16, which might strike the reader as a strange choice. Here is why: economic adjustment in blackboard models is instantaneous but in reality takes time. More importantly, different economic processes take different amounts of time. Standard models with built-in elasticities of substitution deemphasize this crucial idea, and there comes a point at which the model is sufficiently elastic that it can absorb most any external shock with no palpable reaction. Building one's own model forces attention to these details. The models of the paper make some explicit assumptions along those lines but they are not intended to be general, one size fits all. It is also true that in an age in which cell phone processing power is greater than the Cray super computers of the 1970s, there are no computational barriers to making small but realistic models.[46]

Do-it-yourself models can also be custom tailored to data availability and policy questions of local concern in their pattern of aggregation, adjustment mechanisms and portals by which satellite information can be incorporated. If the model turns out to be unrealistic, inaccurate or useless, resource costs are usually less, and more importantly, those who built the model themselves can improve it. Since learning-by-doing is an essential element of multi-lateral development support, the making of the model is in any case highly instructive. A final point is that expensive imported models have a patina of accuracy and sophistication that may not at all be deserved in the local context. Recondite models are themselves causes of lost time and effort and may well not have a commensurate reward. Local model builders, in contrast, may be more willing to give a frank assessment of the model's capabilities and shortcomings, especially if they are responsible for its success or want to push for more data to be collected.[47].

A new wave of analysis derives from recent advances in computer science both in methods and in data structures. More data and better models with which to analyze it are now available. The rise of "big data" is concomitant with more attention being paid to replication of scientific proposals and for ex post evaluation. RCTs are just one component of a vast array of methods that include machine learning and LASSO regression techniques, regression discontinuities and simulation methods as discussed in the penultimate section. What binds these methods in a unified whole is the attempt to give greater voice to data and less to assumed structure. In this regard equation 16 steps forward again because is the kind of implementation that lets the data speak most clearly on its own behalf.

RCT's have come under attack as noted above for selection bias and a number of other quibbles. One must keep in mind however, that if selection bias is present *unless the bias is correlated with the treatment* it makes no difference to the outcome. Politicians may see

[46]See Armenta et al. (2016) for an example of a "compact" CGE applied to a region in Mexico. This model was done in Excel and the General Algebraic Modeling System (GAMS), but many platforms are available, including JAVA, Python and others.
[47]The authors of this report have seen this effect in action!

an RCT application as fraught with political liability, claiming that it is unethical to give some elements of the electorate assistance while withholding help from others. These are all costs of the method but the benefits must also be borne in mind. Without ex post evaluation, scarce project resources can be misspent and lack of accountability can stop the flow of project funds altogether. Accumulated misallocation over time is not without its own ethical implications.

Finally, it is to be noted that RCTs and the other methods described in this paper are not in competition with one another. The paucity of methods in economics generally suggests that performance be audited by the widest range of methods, from micro to macro, all in concert and all, hopefully, in harmony.

References

Alarcón, J.; Ernst, C.; Khondker, B.; Sharma, P.D. 2011. *Dynamic Social Accounting Matrix DySAM: Concept, Methodology and Simulation Outcomes The case of Indonesia and Mozambique* Employment Working Paper 88 (Geneva: International Labour Organization).

Alarcón, J.; Ernst, C.; Sharma, P.D. 2005. *Application of a Green-Jobs SAM with Employment and CO_2 Satellites for Informed Green Policy Support: The Case of Indonesia* Tech. rep. (Vienna: International Input-Output Association).

Armenta, A.B.; Flaherty, D.; Gibson, B.; Salaza-Carrillo, J. 2016. *La reforma energética mexicana y sus efectos regionales: un modelo computable y compacto para Tabasco [Mexican energy reform and its regional effects: a compact, computable general equilibrium model for Tabasco]* Working paper (Burlington, VT: University of Vermont).

Ayres, I. 2008. *Supercrunchers* (New York, NY: Bamtam Books).

Bacharach, M. 1970. *Biproportional Matrices and Input-Output Change* Cambridge. University. Department of Applied Economics. 16 Monographs (Cambridge, UK: Cambridge University Press).

Banerjee, A.; Duflo, E. 2012. *Poor Economics: A Radical Rethinking of the Way to Fight Global Poverty* (New York, NY: PublicAffairs).

Breitschopf, B.; Nathani, C.; Resch, G. 2011. *Review of Approaches for Employment Impact Assessment of Renewable Resource Deployment* Tech. rep. (Vienna: International Atomic Energy Agency).

Clemens, M.A.; Radelet, S.; Bhavnani, R.R.; Bazzi, S. 2012. "Counting chickens when they hatch: Timing and the effects of aid on growth" in *Economic Journal* Vol. 122, No. 561, pp. 590–617.

Colombo, G. 2010. "Linking cge and microsimulation models: A comparison of different approaches" in *International Journal of Microsimulation* Vol. 3, No. 1, pp. 72–91.

de Vet, J.M.; Roy, S.; Schneider, H.; Thio, V.; van Bork, G. 2010. *Review of Methodologies Applied for the Assessment of Employment and Social Impacts* IZA Report 28 (Bonn: IZA).

Diamond, J. 2005. *Collapse: How Societies Choose To Fail Or Succeed* (New York, NY: Viking).

Dintilhac, C.; Fernanda; Ruiz-Nuñez; Wei, Z. 2015. *The Economic Impact of Infrastructure and Public-Private Partnerships: Literature Review* Tech. rep. (Washington, D. C.: World Bank).

Dorfman, R.; Samuelson, P.; Solow, R. 1958. *Linear Programming and Economic Analysis* Rand (New York, NY: McGraw-Hill).

Easterly, W. 2003. “Can foreign aid buy growth?” in *The Journal of Economic Perspectives* Vol. 17, No. 3, pp. 23–48.

Epstein, J. 1999. “Agent-based computational models and generative social science” in *Complexity* Vol. 4, pp. 41–60.

Ernst, C.; Miller, S.; Imschoot, M.V. 2015. *The employment dimension of infrastructure investments: A guide for employment impact assessment* Employment working paper (Geneva: International Labour Organization).

Ernst, C.; Sarabia, M. 2015. *Urgent plan to activate the Egyptian economy* Working Paper 176 (Geneva: International Labour Organization).

Estache, A.; Garsous, G. 2012. *The scope for an impact of infrastructure investments on jobs in developing countries* IFC Economics Notes 4 (Washington D.C.: International Finance Corp of the World Bank Group).

Fernald, L.C.H.; Gertler, P.J.; Neufeld, L.M. 2008. “Role of cash in conditional cash transfer programmes for child health, growth, and development: an analysis of Mexico’s *Oportunidades*” in *Lancet* Vol. 371, pp. 828–37.

Flyvbjerg, B. 2014. “What you should know about megaprojects and why: An overview” in *Project Management Journal* Vol. 45, No. 2, pp. 6–19.

Gibson, B. 2008. “Data problems and empirical modeling in developing economies” in A.K. Dutt; J. Ros (eds.) *International Handbook of Development Economics* (London: Edward Elgar) pp. 83–96.

Gibson, B. 2012. “Trade, employment and the informal sector: An agent-based analysis” in *The Margin: The Journal of Applied Economic Research* Vol. 6, No. 2, pp. 277–306.

Gibson, B.; Flaherty, D. 2016. “Juridical and functional informality: from theory to practical policy” in *Margin: The Journal of Applied Economic Research* Vol. 10, No. 4, pp. 1–37.

Gibson, B.; Kelley, B. 1994. “A classical theory of the informal sector” in *Manchester School* Vol. 62, No. 1, pp. 81–96.

Gow, J.I. 2014. “Public sector innovation theory revisited” in *The Innovation Journal: The Public Sector Innovation Journal* Vol. 19, No. 2, pp. 1 – 22.

Grootaert, C. 2002. *Socieconomic Impact Assessment of Rural Roads: Methodology and Questionnaires* Tech. rep. (Washington, D. C.: World Bank).

Gruber, J. 2011. *Public Finance and Public Policy* (New York, NY: Worth).

Harris, J.R.; Todaro, M.P. 1970. “Migration, unemployment and development: A two-sector analysis” in *The American Economic Review* Vol. 60, No. 1, pp. 126–142.

Herrera, J.; Kuépié, M.; Nordman, C.J.; Oudin, X.; Roubaud, F. 2012. *Informal Sector and Informal Employment: Overview of Data for 11 Cities in 10 Developing Countries* Kennedy School working paper 9 (Cambridge MA: Women in Informal Employment Globalizing and Organizing).

Hettige, H. 2006. *When do rural roads benefit the poor and how?* Tech. rep. (Manila: Asian Development Bank).

Howe, J. 2001. *Socio-Economic Impact of Rural Transport Interventions and Poverty Alleviation* Tech. rep. (London and East Kilbride, Scotland: Rural Travel and Transport Program DFID).

Interdisciplinary Research Consultants. 2014. *Employment Impact Assessment of Infrastructure in three Mediterranean Partner Countries* Tech. rep. (Amman, Jordan: International Labour Oranization).

Irrek, W.; Bunse, M.; Rudolph, F. 2007. *Methodologies for assessing the impacts of climate change on employment and incomes* Tech. rep. (Geneva: International Labour Oranization).

Jarvis, A.; Varma, A.; Ram, J. 2011. *Assessing Green Jobs Potential in Developing Countries: A Practitioner’s Guide* Tech. rep. (Geneva: International Labor Organization).

Kalra, N.; Hallegatte, S.; Lempert, R.; Brown, C.; Fozzard, A.; Gill, S.; Shah, A. 2015. *Agreeing on Robust Decisions: New Processes for Decision Making Under Deep Uncertainty* Policy Research Working Paper 6906 (Washington, D. C.: World Bank).

Kasy, M. 2015. *Why experimenters might not always want to randomize, and what they could do instead* Tech. rep. (Cambridge, MA: Department of Economics Harvard University).

Lewis, W.A. 1954. “Economic development with unlimited supplies of labor” in *The Manchester School of Economics and Social Studies* Vol. 22, No. 2, pp. 139–91.

Lombard, P.; Coetzer, L. 2007. *Estimating the Impact of Rural Road Investments on Socio-Economic Development* Tech. rep. (Washington, D. C.: World Bank).

MacAskill, W. 2015. *Doing Good Better: Effective Altruism and a Radical New Way to Make a Difference* (London: Guardian Faber Publishing).

Mishan, E.; Quah, E. 2007. *Cost-benefit analysis* (London: Routledge).

Organization, I.L. 2013. *Report II: Draft Resolution Concerning Work Statistics* Tech. rep. (Geneva: International Labour Organization).

Schweikert, A.; Chinowsky, P. 2013. *Re-Defining "Project Impact": Incorporating Social Considerations Into The Rural Road Prioritization Process* Proceedings (Boulder: Engineering Project Organization Conference, University of Colorado).

Sennoga, E.B.; Makonnen, N.; Baumont, C.; Turay, S.; Amu, O.; Carreras, E.F.; Mdachi, M.; Ajumbo, G.; Mollinedo, C.; Ngode, E.; Kayobotsi, J.; Karimba, J.; Nyirimana, J.; Okeke, S.; Zeleke, E.; Rutaboba, E.; Munyaruyenzi, P.; Byamukama, B. 2011. *Rwanda: Bank group country stategy paper, 2012-2016* Tech. rep. (Abidjan, Côte d'Ivoire: African Development Bank).

Skott, P.; Auerbach, P. 2003. "Skill asymmetries, increasing wage inequality and unemployment" in M. Setterfield (ed.) *Interactions in Analytical Political Economy: Theory, Policy, and Applications* (Armonk, NY: M.E. Sharpe) pp. 61–66.

Taylor, J.E.; Lybbert, T.J. 2015. *Essentials of Development Economics* (Oakland: University of California Press) 2nd edn.

UNCTAD. 2015. *The Least Developed Countries Report 2015: Transforming Rural Economies* Tech. rep. (Geneva: United Nations Conference on Trade and Development).