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RESOURCE BOOMS, INEQUALITY, AND POVERTY: THE CASE OF GAS IN BOLIVIA

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This paper addresses the question of whether the Bolivian gas boom of the 1990s has bypassed large parts of the poor population, thereby leading to increasing inequalities in an already unequal society. Using a Computable General Equilibrium model that is sequentially linked to a microsimulation model, we examine the transmission channels through which the large resource inflows related to the gas boom, both initial foreign investment in the sector and the subsequent export earnings, as well as large public transfer programs affect the distribution of income. Our focus is on labor market impacts, in particular on shifts between formal and informal employment and changes in relative factor prices. Our simulation results suggest that the gas boom induces a combination of unequalizing and equalizing forces, which tend to offset each other. As net distributional change is limited, growth generated by the boom reduces poverty despite increasing informality.

1. Introduction

In principle, countries richly endowed with natural resources, may it be fertile soils or mineral resources, should be able to prosper and overcome poverty faster than resource-poor countries. Yet, the experience of many resource-rich countries illustrates that this is not necessarily the case. Often, resource-rich countries go through boom and bust cycles that finally leave them poorer than resource-poor countries with similar initial conditions. Through a number of different channels resource wealth may negatively affect economic development.[1] In many instances, tradable sectors become uncompetitive and shrink excessively because export revenues are consumed quickly rather than invested. This can be particularly harmful for economic development, as these sectors, especially manufacturing, are believed to exhibit important positive externalities, whereas resource sectors are often said to have an enclave character with few spillovers to the rest of the economy. In addition to hampering economic development, wealth and income in resource-dependent economies tend to be distributed very unequally, as resource rents typically benefit a small privileged group. As a more unequal distribution of income results in a lower rate of poverty reduction for a given growth rate, it is therefore unlikely that resource-rich countries achieve pro-poor growth, i.e. a growth pattern from which the poor benefit disproportionately, without deliberate interventions in favor of the poor.

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[1]See Auty (2001) and Lay and Mahmoud (2004) for surveys of the literature on the resource curse.

There is an extensive empirical literature on the "resource curse" and the channels through which it operates. Starting with Sachs and Warner (1997), many authors have confirmed that resource-rich countries actually grow more slowly than resource-poor countries using cross-country growth regressions. Yet, it is also increasingly acknowledged that the resource curse is far from inevitable. Rather, the impact of resource booms (and busts) on economic development and poverty as well as the transmission channels depends on both country and resource characteristics, and in particular on the way resource revenues are spent (Lederman and Maloney, 2007). Therefore, a number of country case studies have been undertaken, which have sharpened our understanding of how the resource curse works and how it might be overcome through appropriate public policy responses. Some of these studies, for example the collection in Auty (2001), have focused on the impact of resource wealth on long-term development, whereas other studies have looked at the short to medium run economic impact of a resource boom or bust. The studies in Gelb *et al*. (1988) examine the economic impact of the oil windfalls in the late 1970s on a number of oil-exporting developing economies. These case studies focus on relative price effects, related sectoral shifts, in particular the performance of agriculture, and the fiscal response, especially public investment programs. The case studies included in Collier and Gunning (1998a, 1998b) center on the savings response of public and private agents when faced with trade shocks.

The present paper examines one particular resource shock, namely the gas boom Bolivia experienced in the late 1990s and early 2000s. Following the studies in Gelb *et al*. (1988), we analyze the sectoral shifts and the fiscal response to the gas shock in the short to medium run. In contrast to these studies, our focus is on the poverty and distributional effects of the shock. We consider some of our findings to be of relevance to poor resource-rich countries with similar structural characteristics. The central question is whether the gas boom really bypasses large parts of the (poor) population in Bolivia, thereby leading to increasing inequalities in an already very unequal society. We examine the transmission channels through which the large resource inflows related to the gas boom, both initial foreign investment in the sector and the subsequent export earnings, as well as large public transfer programs (that may well be interpreted as a means of redistributing resource rents) affect the distribution of income. In doing so, we focus on general equilibrium effects and the corresponding labor market impacts, in particular on shifts in formal versus informal employment and changes in relative factor prices. These transmission channels seem to be particularly relevant, as direct employment effects of the resource boom are virtually absent.

To address these issues adequately, we propose a modeling framework that captures the structural features of the Bolivian economy and allows us to trace the poverty and distributional implications of the resource boom-induced changes on the labor market. The framework therefore consists of a multi-sectoral computable general equilibrium (CGE) model that is combined with a microsimulation model. The CGE model allows us to construct counterfactual scenarios to disentangle the effects of the gas boom from other shocks that the Bolivian economy experienced at the same time and to trace the transmission channels at work at the macroeconomic level. Changes in important factor market aggregates from the CGE

model, more specifically changes in relative factor prices and in the workforce composition in terms of formal and informal sector employment, are then passed on to a microsimulation model. The microsimulation model is based on an income generation model estimated on household survey data and produces a counterfactual income distribution given the CGE model results.

The remainder of the paper is structured as follows. The first part provides an overview of the scope and scale of the gas boom that began to shape the Bolivian economy in the late 1990s and a first broad assessment of its macroeconomic impact. It also motivates the counterfactual simulations of the second part. There, we first describe our methodological framework and then present our results. The final section concludes.

2. The Gas Boom and Other Resource Shocks

We consider Bolivia a particularly interesting case for the following reasons. It is the poorest country of South America with a long history of resource-induced booms and busts, and quite some observers have argued that the country's resource wealth is the root cause of its poverty (e.g. Auty and Evia, 2001). The structural reforms of the 1980s and 1990s have been associated with some growth, but that growth has not done the job of lifting large parts of the population out of poverty in an economy with a highly unequal distribution of income, although poverty has been reduced somewhat in the course of the 1990s.

Bolivia's economy has always been and still is highly dependent on natural resources. In the 1990s, hydrocarbons and minerals have typically accounted for roughly 50 percent of exports and the hydrocarbons sector contributes significantly to public revenues. In the second half of the 1990s, huge investments have been undertaken in the gas sector to explore and exploit Bolivia's vast gas reserves. Recent reserve additions have turned Bolivia into the second largest gas reserve holder in Latin America only after Venezuela. A new gas pipeline to Brazil went into operation in 1999 through which the bulk of Bolivia's gas exports run today, and gas exports are expected to increase further in the following years.

The gas shock can be split into three important components: first, the huge investment into the gas sector between 1997 and 2003, most of which was foreign direct investment; second, the gas exports through a new pipeline to Brazil, which went into operation in 1999; and third, the government take of the gas rents. Figure 1 illustrates the magnitude of these components as a share of GDP in the 1990s and early 2000s. Investments in the gas sector reached about 10 percent of GDP in the peak years 1998 and 1999. Unfortunately, more recent figures beyond 2001 are not available. Figure 1 also shows the phasing out of gas exports to Argentina in the course of the 1990s and the gas exports to Brazil, which started in 1999. By 2003, gas exports to Brazil accounted for almost 10 percent of GDP, as they had reached the contracted volume. In addition, gas exports to Argentina are likely to rise again, as new contracts were signed in 2005. Exports will thus mainly fluctuate due to fluctuations in gas prices, which are linked to a basket of international energy prices. High energy prices are also the cause why, by 2005, gas exports accounted for more than 15 percent of GDP. Numbers on the government take from the gas sector are difficult to obtain. Here, we draw on a study by the

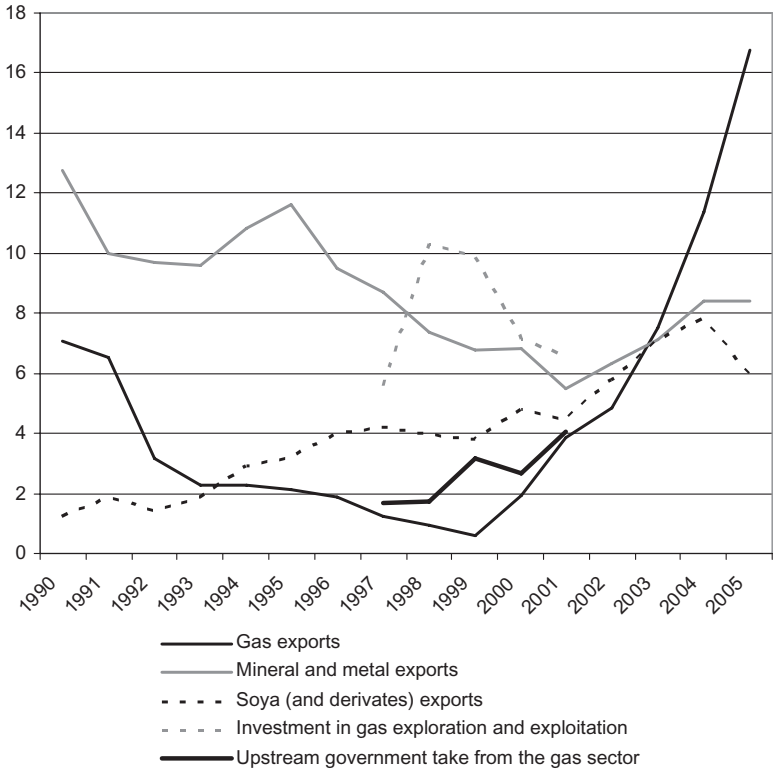


Figure 1. Major Gas-Related Resource Flows as Share of GDP, 1990–2005

Notes: Data on GDP, exports, and investment in gas exploration and exploitation from INE. Upstream government take from the gas sector is from a study of the joint UNDP/World Bank Energy Sector Management Assistance Program (ESMAP, 2002). The government take includes royalties, patents, and taxes on profits.

Source: Authors' calculations.

Energy Sector Management Assistance Program (ESMAP, 2002) of the United Nations Development Programme (UNDP) and the World Bank, which places the government take in 2001 at more than 4 percent of GDP. According to the Ley de Hidrocarburos from 1996, the government take comprises royalties, a profit tax and a tax on remittances abroad, which is why the government take cannot be easily calculated from publicly available budgetary publications.

The gas boom was arguably the biggest but not the only significant external shock. The Bolivian economy was hit by an adverse terms of trade shock in the late 1990s, which comprised falling prices for exports of the four major metals: zinc, gold, tin and silver. These shocks together with a further expansion of soybean production in the Bolivian lowlands had a major impact on the composition of Bolivian exports in the second half of the 1990s and the early 2000s (Figure 2). Hydrocarbon exports rose steeply from less than 10 percent to more than 50 percent of total exports over the period 1999–2005, as did soy and soy derivatives exports from 5 percent in 1990 to more than 20 percent by 2003, a trend that was

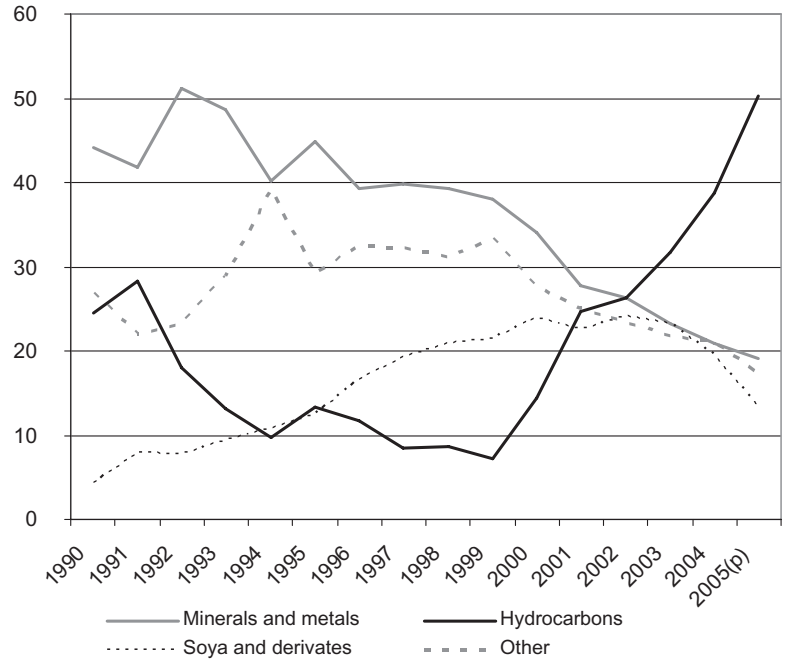


Figure 2. Composition of Exports as Percentages, 1990–2005

Note: Values for 2005 are preliminary.
Source: Data from INE (Instituto Nacional de Estadística) at www.ine.gov.bo.

only interrupted by small dips in El Niño years such as 1992. By contrast, exports of minerals and metals experienced quite some decline from well above 40 percent in the early 1990s to about 20 percent in 2005. On balance, the already high degree of export concentration increased even further and by 2005, the three product groups accounted for 85 percent of Bolivia's exports, with hydrocarbons by far the most important export commodity.

The resource shocks were associated with substantial macroeconomic adjustments. Figure 3 shows the real effective exchange rate and some major balance-of-payments items for the 1990s and the early 2000s. After a real depreciation in the early 1990s, Bolivia experienced a strong appreciation following the inflow of foreign direct investment that was mainly directed at the gas sector. There are thus clear signs of Dutch disease effects in the second half of the 1990s, which appear to dominate the impact of the negative commodity price shock. It has to be noted, however, that in addition to the gas boom, the receipt of aid on a large scale may have contributed to the appreciation of the real exchange rate.[2] In the early 2000s, a dramatic fall in FDI that followed the Brazilian crisis has arguably been the decisive factor behind the real depreciation of the Boliviano.

[2]The possible Dutch disease effects of foreign aid have long been stressed, most recently by Rajan and Subramanian (2005).

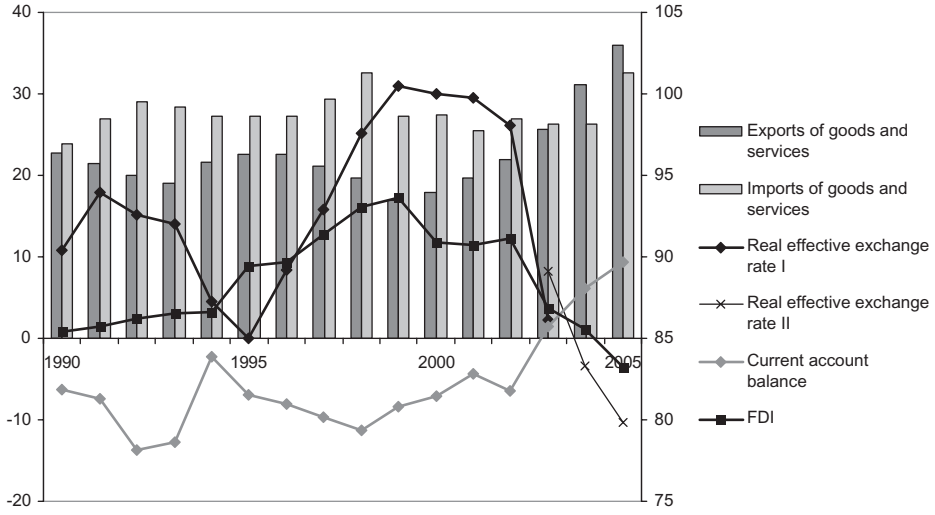


Figure 3. Real Exchange Rate (right-hand scale, 2000 = 100) and Balance-of-Payments Items (as share of GDP, left-hand scale), 1990–2005

Note: Real effective exchange rate time series I and II are not to be overlaid due to statistical changes.

Source: Data from IMF International Financial Statistics (January 2007).

The current account deteriorated until 1999; imports increased and exports fell. Only after 2000 did exports start to recover, led by rising gas deliveries to Brazil. The dramatic decrease in exports in the second half of the 1990s can of course not entirely be attributed to the export sectors losing competitiveness because of real exchange rate appreciation. Another important factor was the commodity price shocks for Bolivia's major exported metals. In addition, the Brazilian crisis from 1999 negatively affected Bolivia's export demand, all the more so as the trigger of the crisis was a massive devaluation of the Brazilian Real.

The gas boom and other external shocks also had some impact on sectoral growth rates in the second half of the 1990s. When studying the Bolivian national accounts, one will find that the gas boom after 1996 appears to have triggered a tremendous construction boom. Yet, according to personal correspondence with Instituto Nacional de Estadística (INE), these figures reflect the construction of the gas pipeline to Brazil, with the bulk of pipeline-related construction works entering the national accounts in 1998. When pipeline construction is deducted, there are still signs of a temporary, yet less pronounced increase in construction activities in the late 1990s (Appendix 1). As Figure 4 indicates, overall sectoral change in the 1990s has been modest. The most important non-tradable sector, the services sector, seems to have benefited from the investment boom in the gas sector, as it grew significantly stronger after 1996. This is an indication of Dutch disease-type adjustments. In the early 2000s, the sector contracted again, which probably reflects the steep fall in FDI and the concomitant real depreciation. Starting from a very low base, modern agriculture, one of the most export-oriented sectors, expanded very strongly in the 1990s, while traditional agriculture experienced the

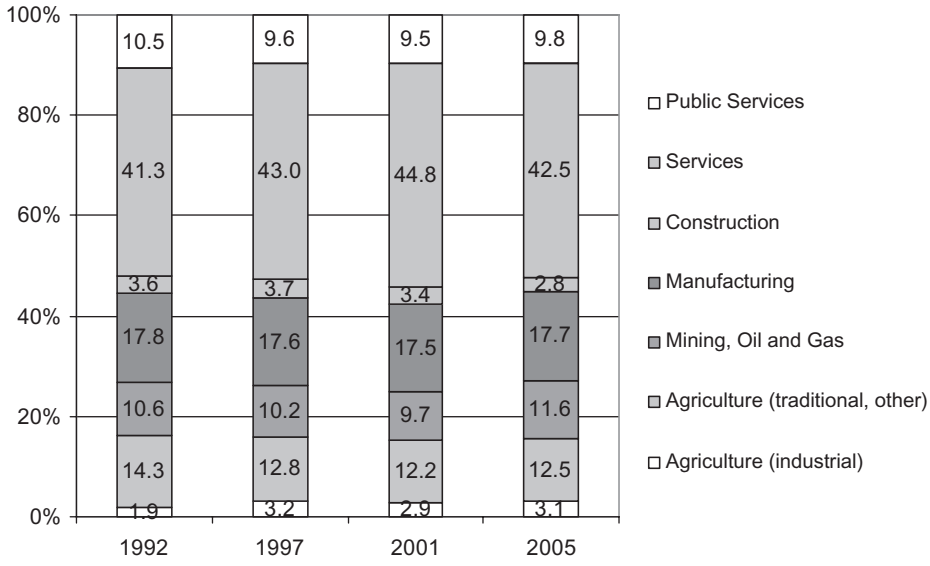


Figure 4. Sectoral Shares in GDP, 1992–1997–2001

Source: Data from INE (www.ine.gov.bo, 2005).

lowest growth rates, its importance therefore declining. The main factor behind the drop in modern agriculture's share after 1997 is arguably not the gas boom and the associated real appreciation, but rather the 1997/98 El Niño, which caused planted soybean areas to contract.

As regards changes in employment, in particular shifts between formal and informal employment, there is strong evidence of increasing informality in the late 1990s in Bolivia. Spatz (2004) finds a drop in the formal sector share from 55 percent in 1997 to only 50 percent in 2001. Using different data and a slightly different definition of the informal sector, Tannuri-Pianto *et al*. (2004) detect an even more pronounced decrease in formal employment (from 44 percent in 1997 to 32 percent in 2002).[3] The gas boom is one potential factor behind these developments. Klasen *et al*. (2007) stress the importance of tight labor market regulations in the presence of negative external shocks as another possible cause of increasing informality.

The preceding analysis suggests that the gas boom provided substantial (additional) fiscal resources to the Bolivian government. A key question is whether these resources have been directed towards the poorer parts of the population. Possibly somewhat surprisingly, the Bolivian fiscal stance deteriorated during the period under investigation despite these additional resources. In 2003, the overall budget deficit amounted to 8 percent of GDP. The root cause of the fiscal problems is what many observers have perceived as a failed pension reform that dates back to 1996. It should be noted that pension payments out of the old pay-as-you-go

[3]Galli and Kucera (2003) provide some evidence that informality increased only slightly over the period 1990–1997, which suggests that the process of informalization accelerated in the late 1990s.

system in Bolivia represent a highly regressive transfer, as they cover 2 percent of the Bolivian population at the incredible cost of 5 percent of GDP (World Bank, 2004).

Increased spending on social security left little room for raising expenditure targeted at the poorer parts of the population. Nevertheless, pro-poor expenditure in basic social services, defined as expenditure in primary and secondary education, primary health care, and the Bonosol[4] payment, increased from 9.1 (27) to 12.4 (33) percent of GDP (total public expenditure) between 1995 and 2002. It should however be taken into account that about half of Bolivia's basic social expenditure is funded by donors and official loans. Studying the effectiveness of these expenditure shifts goes beyond the scope of this paper.

Yet, the increasing share of pension payments certainly represents the major public expenditure shift that can be observed during the period under investigation. It may be seen as a consequence of bad fiscal management and a badly implemented reform. We are however inclined to interpret this expenditure shift as being related to the expectation of the windfall profits from gas exports and hence as a way to transfer resource rents to the population—although this interpretation is of course open to debate.

3. Assessing the Impact of the Gas Shock

Having established that resource shocks, and in particular the gas boom, were associated with major adjustments in the Bolivian economy, we now turn to a counterfactual analysis in which we examine the impact of the gas boom in isolation from other factors such as the inflow of foreign aid and FDI.

3.1. *The Modeling Framework*

In our counterfactual analysis, we combine a CGE model with a microsimulation model, connecting the two through several link variables.

The CGE Model

The CGE model provides a standard recursive-dynamic, trade-focused representation of the national economy.[5] However, to make it applicable for the analysis of the gas boom, the model differs from the typical specification in two important respects: first, production is split up into formal and informal activities. Such a distinction enables us to examine one possible channel through which the gas boom and the associated real appreciation might have had a negative distributional impact, namely by forcing workers to switch from more productive formal activities to less productive informal activities. This mechanism is similar in

[4]The Bonosol payment was introduced in the late 1990s as an annuity to be paid to every Bolivian aged 65 or more out of the proceeds of privatization. The first payment of US$ 212 was made in 1997. The government however soon realized that such an amount would not be sustainable and reduced the annual payment to US$ 60 (under a new name "Bolivida"). Bolivida payments however were not processed until 2001. Political pressure led the Sanchez de Lozada administration to reinstitute the Bonosol payment of US$ 240 in 2003. See Escobar and Nina (2004) and Martinez (2004) for details.

[5]Van der Mensbrugghe (2003) gives a technical description of the prototype CGE model on which our model is based.

spirit to those assumed in much of the literature on the resource curse. Sachs and Warner (1997), for example, argue that resource booms tend to be detrimental to economic growth as Dutch disease effects lead to a contraction of sectors exhibiting positive externalities. Second, exploration and pipeline construction are considered as separate investment demand categories in order to model the huge investment outlays that preceded the expansion of the gas sector.

On the production side, the model differentiates between activities and commodities, thus allowing for the same commodity to be produced by one or more sectors, and for the same sector to produce one or more commodities. To take just one example, the modern agricultural sector not only grows cash crops such as soybeans, but is also engaged in livestock farming. Sectoral output results from combining intermediate goods and six different primary factors (skilled labor, unskilled labor, formal capital, informal capital, land, and a sector-specific resource in the case of oil and gas) in a nested Constant Elasticity of Substitution (CES) structure with four tiers (Van der Mensbrugghe, 2003). The top-level nest is a fixed-coefficient Leontief production function that combines aggregate value added and intermediate inputs. All other tiers use CES specifications. The second tier decomposes aggregate value added into aggregate demand for capital and labor, aggregate land demand, and a sector-specific resource in the case of gas. The third-level nest decomposes the capital–labor bundle into unskilled labor and a bundle composed of skilled labor and capital. Finally, the fourth nest decomposes the capital–skilled labor bundle.

International trade is specified along conventional lines, with import demand being derived from a CES aggregation function of domestic and imported goods, and export supply from a Constant Elasticity of Transformation (CET) function of domestically sold and exported goods. Import supply and export demand are infinitely elastic, i.e. the small-country assumption holds.

The disaggregation of production, which is based on a Social Accounting Matrix (SAM) for 2001, reveals structural differences between formal and informal operations, even though they are not as clear-cut as theoretical models tend to suggest (Table 1).[6] Regarding trade orientation, the sectors with the highest trade shares are all formal, but since several other formal sectors produce pure non-traded goods, we can only tentatively hypothesize that the gas boom has led to an informalization of the economy via Dutch disease effects. A more pronounced pattern emerges with respect to the composition of factor income. It turns out that all informal activities make intensive use of unskilled labor, whereas capital intensity is high in most formal activities.

The extended functional income distribution shown in Table 1 reflects certain assumptions about how factor markets operate in the short to medium term. We distinguish two categories of capital that are specific to formal and informal activities, respectively. Formal (informal) capital is partially mobile within the formal (informal) economy, which is modeled by means of CET functions, with the sectoral allocation of formal (informal) capital determined by relative rates-of-return to capital and a transformation elasticity parameter reflecting the ease

[6]Details on the construction of the SAM, in particular on the formal–informal split and the use of household survey information are given in Appendix 2.

TABLE 1

Structural Characteristics of the Bolivian Economy

	Trade Orientation		Factor Income as Share of Value Added					
Sectors	Imports	Exports	LabU	LabS	KapInf	KapForm	LandR	NatRs
TradAgr	0.07	0.02	0.67				0.33	
ForFis		0.09	0.56	0.33		0.02		0.09
Formal								
ModAgr	0.09	0.16	0.20	0.27		0.25	0.28	
OilGas		0.31		0.11		0.31		0.58
Exploration				0.09		0.91		
FoodPro	0.07	0.14	0.26	0.23		0.50		
OthLiMan	0.20	0.14	0.34	0.36		0.30		
Chem	0.53	0.02	0.35	0.05		0.60		
OilRef	0.12	0.02	0.02	0.10		0.88		
Min	0.11	0.37	0.18	0.09		0.73		
HeavMan	0.60	0.20	0.51	0.27		0.22		
EleGasWat			0.01	0.16		0.82		
Const			0.30	0.28		0.43		
Trade			0.17	0.33		0.50		
Trans	0.06	0.05	0.37	0.27		0.36		
CommFinBus	0.04	0.03	0.03	0.27		0.70		
RealEst						1.00		
SocPerServ	0.02	0.01	0.13	0.37		0.50		
HotRest	0.05	0.05	0.31	0.21		0.48		
PubServ			0.07	0.93				
Informal								
FoodPro	0.07	0.15	0.50	0.20	0.30			
OthLiMan	0.20	0.14	0.51	0.19	0.30			
Const			0.55	0.09	0.36			
TradeDomS			0.49	0.21	0.30			
Trans	0.06	0.05	0.43	0.20	0.36			
HotRest	0.05	0.05	0.44	0.10	0.46			

Note: Imports are calculated as a share of absorption, exports as a share of domestic production. Labels are explained in Appendix 3.

Source: Authors' calculations based on the Social Accounting Matrix for 2001.

with which capital can be reallocated. Only if the supply elasticity is infinite, the law-of-one-price holds, and capital is fully mobile. Given the medium-run time horizon of our analysis, the capital mobility parameter has been restricted to a fairly low level of 0.5. In addition, our specification does not allow land to be shifted between modern and traditional agriculture given that the two activities are regionally separated.[7] The natural resource is sector-specific; its supply is a positive function of the resource price relative to the economy-wide price level. The market for unskilled labor is segmented between rural and urban areas, where modern agriculture is considered part of the urban economy, as it resembles other (formal) urban activities in using wage labor and formal capital rather than relying on self-employment. The two segments are linked through rural–urban migration. Along the lines of the Harris–Todaro model, the decision to migrate depends on wage differentials. Skilled labor is assumed to be fully mobile across production sectors. Market clearing is achieved via wage adjustments, but the intersectoral

[7]Note that the model allows for both limiting cases—perfect capital (land) mobility and perfect capital (land) immobility—as well as any intermediate case due to the CET specification.

TABLE 2
SECTORAL DEVIATIONS FROM AVERAGE WAGES

	Skilled Labor		Unskilled Labor	
Sectors	Formal	Informal	Formal	Informal
Food Pro	2.85	1.27	3.26	2.57
OthLiMan	0.65	0.38	1.31	0.94
Const	0.65	0.29	0.97	0.54
Trade	0.42	0.27	0.50	0.49
Trans	1.67	1.03	3.72	2.30
Hot Rest	0.59	0.33	1.15	0.70

Note: A value above (below) one indicates higher-than-average (lower-than-average) wages.
Source: Authors' calculations.

wage differentials observed in the base period are assumed to persist. These differentials point to systematically lower labor productivity in informal sectors. Unskilled workers, for example, receive only slightly more than half the average wage in the informal construction sector, while they are almost paid the average wage in the formal sector (Table 2). These formal–informal productivity differences are confirmed by the household survey data. In almost all sectors, average wages in formal activities are significantly higher than informal "wages" that we impute by subtracting an informal capital component (corresponding to the value added share from the SAM) from self-employment income.

The factor income generated in the production process is distributed to four different household groups—(asset) poor and rich urban households as well as (asset) poor and rich rural households—according to fixed coefficients derived from the SAM. These coefficients are derived from the household survey data, where poor and rich households are simply identified by their average skill level in terms of formal education. Moreover, households receive transfers in fixed proportions to government expenditures and remittances from abroad that are fixed in foreign currency. The transfer shares are also based on household survey information. They use their gross income to pay taxes, to save and to consume. The allocation of consumption expenditures on different goods is modeled employing a Linear Expenditure System (LES). Information on broad differences in expenditure shares between household groups (food vs. non-food consumption) comes from the household survey although we have not made the attempt to exactly match commodities of the SAM—so we respect the total consumption of each commodity given by the national accounts.

The sectoral allocation of government and the non-gas component of investment demand are both governed by fixed coefficients, whereas investment demand for exploration and pipeline construction is exogenously given. Despite exogenous gas-related investment,[8] the model is savings-driven, i.e. other, non-gas investment adjusts so as to bring about the necessary ex-post identity of savings and total investment. This "macroeconomic closure" implies that any public deficit is financed by private savings, thereby reducing private investment. The closure is

[8]We assume that investment in the gas sector is financed by (a perfectly elastic supply of) foreign direct investment; see below.

distribution neutral as private consumption is unaffected by the public deficit. A neoclassical closure seems appropriate given the distribution focus and the medium-term horizon of the analysis.[9]

The balance of payments equilibrium is determined by the equality of exogenous foreign savings to the value of the current account. With fixed world prices and a fixed nominal exchange rate, equilibrium will be achieved through movements in the domestic price level that affect export and import prices relative to domestic good prices, i.e. the real exchange rate.[10] Alternative foreign exchange market closure choices are possible. In fact, what the model determines is a stable relationship between the real exchange rate and the balance of payments current account. In the macro closure for the government, the budget deficit is allowed to adjust in order to achieve a predetermined level of real government expenditures at fixed direct and indirect tax rates.

A simple recursive-dynamic framework allows us to implement the gas boom as a sequence of shocks (see below) and to trace over time the changes in economic structure caused by the boom. There are four elements driving model dynamics—exogenous labor growth, investment-driven capital accumulation, exogenous growth of natural resources in the gas sector, and exogenous productivity growth. Several other exogenous variables require updating to arrive at a realistic baseline scenario. Government expenditures and transfers, for example, are assumed to grow at the same rate as GDP.

Finally, the CGE model is linked to the microsimulation model. We assume that the link is sequential, i.e. the CGE model is solved first and certain target values are passed to the microsimulation that is "forced" to reproduce the aggregate changes in these targets. In line with our focus on skilled vs. unskilled labor and formal vs. informal employment, the following link variables are used: (1) the formal share of unskilled workers, (2) the formal share of skilled workers, (3) mean wages for skilled workers, (4) mean wages for unskilled workers, and (5) mean informal profits.[11] While the first four link variables have a straightforward interpretation, the fifth is based on the concept of mixed income received by self-employed workers. Accordingly, informal profits are calculated as the sum of skilled and unskilled labor income as well as informal capital income.

Before we discuss the specification of the microsimulation model, it should be stressed that the CGE and the microsimulation model should not be seen as a consistent macro–micro modeling framework. Rather, the idea of combining these two types of simulation models in a sequential fashion is to get "the best of the two modeling worlds." The CGE model is a useful tool to examine the transmission

[9]Alternatively, in an investment-driven model, investment would be fixed and at least one household's savings would have to adjust to finance the public deficit (that results from fixed government consumption) and to achieve savings–investment balance. The investment-driven closure is best suited for short-run models that allow for Keynesian multiplier effects.

[10]For example, additional capital inflows lead to a real appreciation, so that domestic prices rise relative to export and import prices. Given the export supply and import demand functions, the result will be lower exports and higher imports. Thus, from an initial equilibrium, any rise in foreign savings will lead to a new equilibrium with a lower (appreciated) exchange rate.

[11]Although formal profits account for an important share in value added, they are not passed to the microsimulation for two reasons. First, most formal profits are retained and invested. Second, capital income is likely to be measured very poorly in household surveys. As formal profits increase considerably during the gas boom, we may systematically ignore an inequality-increasing factor.

channels of the resource boom. It provides a consistent modeling framework based on an empirical representation of the Bolivian economy and yields a numerical counterfactual approximation of the shocks' labor market impacts. Yet, in order to assess the ultimate poverty and distributional consequences of the shocks, the microsimulation is a much more suitable tool. It takes into account household heterogeneity in terms of factor endowments at a much more detailed level and models occupational choices and corresponding earnings changes at the individual level. Sequentially combining these models typically implies the imposition of a number of ad-hoc assumptions that may not be satisfying from a theoretical perspective.

The Microsimulation Model

The microsimulation model is based on an income generation model that is estimated on household survey data.[12] We use the Encuesta Continua de Hogares from 2001. The following estimations are based on all individuals employed outside traditional agriculture, as our focus is on changes in formal vs. informal employment. In contrast to the CGE model, the microsimulation hence assumes that smallholders remain in their occupation.

The two basic components of this income generation model are a model of occupational choices that represents the "choice" between formal and informal employment[13] as well as earnings functions that correspond to the respective sector of employment. If individuals happen to be in (or switch to) the formal sector they are assumed to earn a wage, whereas individuals in the informal sector are assumed to be (or become) part of a household enterprise and contribute to the profits earned by this enterprise. Table 3 provides an overview of the equations of the income generation model, the econometric models, the sub-samples and lists of the explanatory variables. We limit the discussion of the specification to innovative and interesting features. As estimation results correspond to expectations, we do not further comment on them here, but report the detailed results in the Appendices 4 and 5.

The choice between informal and formal activities is estimated separately for household heads, spouses, and other household members using a logit model. The equations of the choice model are interrelated through the head's wage (and hence her choice) entering the occupational choice model of spouses and other household members. We hence assume a sequential choice with the household head deciding first.

In addition to the formal–informal segmentation, we assume segmentation according to skill levels, differentiating between unskilled and skilled labor (defined in terms of years of schooling). We therefore estimate separate wage equations for unskilled and skilled labor employed in the formal sector. We test for

[12]The income generation model is based on a model first proposed by Alatas and Bourguignon (2005) to decompose inequality and poverty changes between two household surveys. See Bourguignon *et al*. (2005) for a selection of country studies using this type of decomposition technique. It has also been used in a macro–micro simulation framework by Robilliard *et al*. (2002) and Bussolo and Lay (2005).

[13]Employment is assumed to be informal if the individual is a self-employed/non-remunerated household member and/or works in an enterprise with less than five employees.

TABLE 3

OVERVIEW OF THE INCOME GENERATION MODEL

	Explained Variable and Estimated Equation	Model	Sub-Sample	Explanatory Variables
1	Being in formal or informal sector $P(formal = 1\|X^h) = g(c^h + X^h\alpha^h)$	Logit	Heads	Education (squared), experience, female, share of formal workers in province of residence
2	Being in formal or informal sector $P(formal = 1\|X^s) = g(c^s + X^s\alpha^s)$	Logit	Spouses	Education (squared), experience, female, indigenous, geographical dummies, number of children under 10 (interacted with female), share of formal workers in province of residence, log wage of household head (if head formal)
3	Being in formal or informal sector $P(formal = 1\|X^o) = g(c^o + X^o\alpha^o)$	Logit	Others	Education (squared), experience, female, widow, number of children under 10 (interacted with female), share of formal workers in province of residence, log wage of household head (if head formal)
4	Unskilled wage $\ln w^{us} = c^{us} + X^{us}\beta^{us} + uw^{us}$	Linear	Unskilled formal sector	Education (squared), experience (squared), female, geographical dummies
5	Skilled wage $\ln w^{sk} = c^{sk} + X^{sk}\beta^{sk} + uw^{sk}$	Linear (selection corrected)	Skilled formal sector	
6	Profits of household enterprise $\ln p = c^p + X^p\beta^p + up$	Linear	Informal sector enterprises (max. one per household)	Average education of members (squared), Average experience of members (squared), number of female enterprise members, geographical dummies, number of enterprise members

self-selection into formal activities that we find to play a role only for the skilled. Hence, the wage equation for the unskilled is estimated using OLS, while we correct for selection bias for the skilled using the provincial formal employment share as identifying restriction.[14] The set of explanatory variables (reported in Table 3) is standard. The individuals in the informal sector are assumed to pool resources and work effort in a household enterprise, for which we estimate a profit function. The number of household members employed in this informal activity enters as explanatory variable. As the number of household members working in the enterprise is likely to depend on the prospective profits to be earned in informal activities, we have tried to instrument this variable with the provincial formal employment share, which left coefficients unchanged.

These estimated relationships form the basis of the microsimulation. The microsimulation is shocked using changes in the five link variables that are passed on from the CGE analysis. To gain an understanding of how the microsimulation works, it is useful to think of the set of equations summarized in Table 3 as a system of equations.

Let employment n be the sum of n^{us} and n^{sk}, the number of unskilled and skilled labor, respectively.

$$n^{us} + n^{sk} = n.$$

fs^{us} denotes the formal share of employment among the unskilled. The number of formal unskilled nf^{us} is given by the sum of heads, spouses, and other household members that derive a higher "utility" from being employed in the formal than from being employed in the informal sector where $(ind_{us\_h}(\hat{c}^h + X^h\hat{\alpha}^h + uh1 > uh0)$ is an indicator function assuming 1 if the condition in brackets is fulfilled and 0 otherwise. $uh0$, $uh1$, $us0$, $us1$, $uo0$, $uo1$ are residuals for heads, spouses, and others, respectively, that cannot be observed in latent variable models and are hence drawn consistent with the observed choice.

$$fs^{us} = \frac{nf^{us}}{n^{us}} \tag{1}$$

where:

$$\sum_{us\_h} ind_{us\_h}(\hat{c}^h + X^h\hat{\alpha}^h + uh1 > uh0) + \sum_{us\_s} ind_{us\_s}(\hat{c}^s + X^s\hat{\alpha}^s + us1 > us1) + \sum_{us\_o} ind_{us\_o}(\hat{c}^o + X^o\hat{\alpha}^o + uo1 > uo0) = nf^{us}$$

We have the same set of equations for skilled labor:

$$fs^{sk} = \frac{nf^{sk}}{n^{sk}} \tag{2}$$

[14]In line with the occupational choice model, the selection equation is estimated using a logit-model. As suggested by Lee (1983), we first compute the value of the inverse normal cumulative density at the fitted values of the logit. These transformed fitted values are then used to compute the inverse Mills' ratio.

where:

$$\sum_{sk\_h} ind_{sk\_h}\left(\hat{c}^h + X^h\hat{\alpha}^h + uh1 > yh0\right) + \sum_{sk\_s} ind_{sk\_s}\left(\hat{c}^s + X^s\hat{\alpha}^s + us1 > us1\right) + \sum_{sk\_o} ind_{sk\_o}\left(\hat{c}^o + X^o\hat{\alpha}^o + uo1 > uo0\right) = nf^{sk}$$

The mean unskilled wage is the wage of all unskilled workers in the formal sector divided by the number of unskilled formal workers:

$$(3) \qquad mean\left(w^{us}\right) = \frac{\sum_{us\_h} ind_{us\_h}(..)w^{us}_{us\_h} + \sum_{us\_s} ind_{us\_s}(..)ws^{us}_{us\_s} + \sum_{us\_o} ind_{us\_o}(..)w^{us}_{us\_s}}{nf^{us}}$$

where $w^{us} = \exp\left(\hat{c}^{us} + X^{us}\hat{\beta}^{us} + \hat{u}w^{us}\right)$ is the individual unskilled wage with $\hat{u}w^{us}$, the observed residual. The same equation holds for the skilled:

$$(4) \qquad mean\left(w^{sk}\right) = \frac{\sum_{sk\_h} ind_{sk\_h}(..)w^{sk}_{sk\_h} + \sum_{sk\_s} ind_{sk\_s}(..)ws^{sk}_{sk\_s} + \sum_{sk\_o} ind_{sk\_o}(..)w^{sk}_{sk\_s}}{nf^{sk}}$$

where $w^{sk} = \exp\left(\hat{c}^{sk} + X^{sk}\hat{\beta}^{sk} + \hat{u}w^{sk}\right)$.

Whereas wages are summed over individuals, total profits from informal activities are summed over households (*hh*):

$$(5) \qquad mean(p) = \frac{\sum_{hh} p_{hh}}{n - nf^{us} - nf^{sk}}$$

where the profit p_{hh} in household *hh* will only be greater than 0 if at least one member is employed in the informal sector.

$$(6) \qquad p_{hh} = \exp\left(\hat{c}^p + X^p\hat{\beta}^p + \hat{u}p\right)(-1)\left[(ind_h(..)-1) + (ind_s(..)-1) + \sum_o (ind_o(..)-1)\right].$$

Remember also that the number of (skilled and unskilled) household enterprise members enters the profit function.

$$(7) \qquad X^p = f\left(ind_h(..); ind_s(..); \sum_o ind_o(..)\right).$$

The above equations describe the initial distribution of labor income (with the exception of traditional agriculture). As mentioned above, the microsimulation is "forced" to reproduce the changes in the aggregates given by the CGE model. This is achieved by varying the constants in the above system of equations such that the household income generation model just reproduces the target values. Increasing, for example the constant $\hat{c}^h$ leads some heads to switch from informal to formal

activities. When individuals switch from informal to formal activities, they are assigned a simulated wage residual, as we do not have an observed unexplained wage $\hat{u}w$ for her. The same holds if an individual becomes the first household member active in the informal sector, thereby creating a new enterprise (not if she joins an existing enterprise).[15] If an individual joins a household enterprise, this individual's characteristics will change the profits of the enterprise by changing some of the profit determinants, as for example the average education, experience, and, most importantly, the number of members active in this informal enterprise. If an individual creates one, only her characteristics determine those profits. A final example illustrates the simultaneous character of the occupational choice decisions within a household. When the CGE model passes higher skilled wages to the microsimulation, the solution algorithm will increase $\hat{c}^{sk}$. Some of those skilled workers will be household heads whose higher wages positively enter the choice equations of spouses and other household members, raising the probability that the latter change occupation.

The above income generation model represents only part of the income households receive. It focuses on income generation in non-agricultural sectors and translates changes in labor incomes and the formal–informal composition of employment into poverty and distributional changes. Other income sources include income from traditional agricultural activities (including home-consumed production) and all kinds of transfer incomes from remittances to public transfers. Agricultural incomes of smallholders from the household survey will be scaled up using a weighted real factor price index for traditional agriculture (real factor prices for land and unskilled labor are weighted with the share in value added of the sector). Changes in public transfers and changes in other income sources will not be taken into account in our counterfactual microsimulation of the gas boom. Public transfers will also grow or decrease in accordance with the CGE model. It should however be borne in mind that these income sources and changes therein do not affect individual behavior (at least in our model).

Finally, we want to point to an important drawback of the proposed type of labor market microsimulation model. It concerns the simulation of occupational transition based on state comparisons. The above income generation model implicitly assumes that the estimated propensity to *be employed* in the informal/formal sector, is closely related to the propensity to *change* occupation. Whether this assumption holds true is an empirical question, which could (and possibly should) be addressed using panel datasets or information on individual employment histories. Unfortunately, such data are not available for Bolivia.

[15]To adjust to the targets, we need to vary the constants in the occupational choice equations differently for unskilled and skilled labor, respectively. This implies that we fix the (absolute) differences between the occupational choice model constants for heads, spouses, and others for both unskilled and skilled labor. If one thinks of this problem in terms of solving the system of equations to reach the new target values, this means that the occupational constants (i.e. for heads, spouses, and others) for each skilled segment are augmented by the same amount. We now have five variables (two "vectors" of constants of the choice models and three wage/profit constants) and five equations. The system is solved using a Newton–Raphson algorithm.

TABLE 4

Marginal Effects of Changes in Link Variables on Urban Inequality and Poverty (point differences)

Scenario	P0	P1	Theil
		Urban	
Initial	50.8	23.5	63.3
5% point decline in formal share unskilled	0.7	0.5	−1.2
5% point decline in formal share skilled	1.6	0.8	1.1
10% increase in unskilled wages	−0.9	−0.7	−1.1
10% increase in skilled wages	−0.6	−0.3	2.4
10% increase in informal profits	−1.6	−1.1	−1.3

Source: Authors' calculations.

3.2. *Results*

Stylized Simulations for Link Variables

While in the gas shock simulations presented below all link variables change simultaneously, the importance of specific labor market link variables for poverty and inequality can be seen more clearly if they are considered in isolation. Consequently, we performed stylized simulations for each link variable, the results of which are reported in Table 4. Since the mechanics of the income generation model can be better understood when looking at the urban population only, we restrict the results to this group. It turns out that, at constant factor prices, a lower formal employment share (by 5 percentage points) leads to a significant rise in urban poverty. The effect is markedly stronger for skilled workers. Yet, urban mean per capita income declines by 2.83 percent when informality increases among unskilled labor, much more strongly than the 1.72 percent decline recorded for skilled labor.[16] This seemingly paradox result can be explained by looking at the distributional shifts. Whereas increasing informality is equalizing for unskilled labor, as indicated by the decrease in the Theil Index, it is inequality-increasing for skilled labor. This rise in inequality reinforces the negative poverty effect of declining incomes for skilled workers. A more detailed analysis of the distributional impact that looks at the entire distribution rather than aggregate indicators reveals striking results (see Appendices 6 and 7): for both unskilled and skilled labor, the very poor are affected most by increasing informality.

These results can be rationalized by looking at who moves into informality as well as the size of the income loss for movers relative to both their initial income, the income losses incurred by other individuals, and indirect effects. The size of the income loss depends on individual characteristics (as the returns to these characteristics differ between formal and informal activities). From the estimation that underlies the microsimulation we know that less educated younger (and hence poorer) individuals tend to move into informality first. Furthermore, the estimation results for wages and profit functions indicate that the returns to individual characteristics, education and age, are higher in formal than in informal activities

[16]The per capita income decline is stronger for unskilled labor since this skill group accounts for a much larger share of the workforce.

(see Appendix 5). This implies that the income loss of moving into informality is higher for more educated and older (or more experienced) individuals.

Beyond the estimation results, the mechanics of the microsimulation have to be taken into account. If relatively unskilled workers leave the formal sector first, those who remain formally employed will have, on average, higher wages than those who left and the average formal sector wage increases. If we now force formal wages to be constant—as we do in the stylized simulations—each individual who remains formal will be assigned a lower wage. The microsimulation achieves this by lowering the constant for formal sector wages. It should not be forgotten that a household head's formal sector wage now enters the choice equation of other household members. Our analysis suggests that these effects can be fairly important. It is the combination of the immediate impact and these indirect effects that eventually explains the poverty and distributional outcomes.[17] It should be noted that the stylized simulations here do not constitute economically meaningful experiments, as they assume changes in informal–formal shares without consequences on wages and profits. Without a CGE model these models can only be used for illustrative or decomposition purposes.

It is now easier to understand the above distributional consequences of the decline in formal employment. Less educated (and hence poorer) individuals move into the informal sector first where earnings are lower because of lower returns to education and experience as well as a lower fixed component of income (the constant). These losses are relatively large compared to initial income for the poor, which explains the strong negative income growth in the lower parts of the income distribution. This holds for both the unskilled and skilled workforce.

A similar reasoning explains why unskilled workers from middle-income classes do not suffer significant income losses. In middle-income ranges, fewer unskilled formal workers lose their jobs and if they do their relative income loss is not too high. Yet, higher educational endowments are associated with higher income losses (the returns to education are lower in informal activities), which is why the growth incidence curve is downward sloping for higher incomes. This effect seems to dominate at higher incomes and explains the overall "positive" distributional impact among unskilled workers.

The negative distributional shift when informality increases among skilled workers is not only due to the strong losses of the poor. Income losses are relatively evenly distributed between the 20th and 80th percentile, which explains the relatively strong impact of skilled formal employment losses on poverty. For skilled workers the differences in returns to education between formal and informal activities are even more pronounced than for unskilled workers.[18] The very rich do not seem to be affected at all or even experience slightly positive income gains. This is mainly due to the very low incidence of informal work among high-skilled workers. Furthermore, individuals from richer households may join well-functioning existing enterprises, which may result in additional household enterprise income higher than former individual wage income.

[17]Furthermore, differences in the variance of the simulated residual also play a role for the distributional impact, but this effect should not be too large.

[18]See Appendix 5.

The poverty and distributional effects of increases in different types of labor incomes are in line with expectations. An increase in unskilled wages decreases poverty and improves the distribution of income. Maybe somewhat less obvious is the relatively strong reduction in the headcount index associated with an increase in skilled wages. Yet, the impact on P1 is much less pronounced, indicating that the "skilled poor" are close to the poverty line, and the overall income distribution worsens quite substantially compared to the distributional improvements that can be reached, for example, by an increase in unskilled wages. Increases in informal profits turn out to reduce poverty most effectively.

Gas Shock Simulations

We now turn to a counterfactual analysis of the gas shock. We use the CGE model in combination with the microsimulation model to evaluate the distributional and poverty impacts of a gas boom over the period 1997–2005 by simulating two scenarios. The *first scenario* combines a positive temporary demand (investment) shock with a delayed positive supply shock. The size of the shocks roughly corresponds to what Bolivia actually experienced (see above). The demand shock consists of a doubling of real investment demand in exploration and pipeline construction over the period 1998–2001, which is financed by foreign capital inflows. After 2001, foreign direct investment in the oil and gas sector is assumed to fall back to the pre-shock level. The upfront investment is assumed to induce a positive supply shock from 2004 onwards, which is modeled by quadrupling oil and gas reserves, i.e. the specific factor used in oil and gas production. The *second scenario* combines the first scenario with a progressive reallocation of parts of public revenues to households, as observed in the household surveys. More specifically, it is assumed that real government transfers to poor rural, poor urban, and all rich households increase by 100, 50 and 10 percent (and again by 50, 25, and 5 percent), respectively, from year 2000 (from year 2004) onwards. This scenario takes into account the mainly transfer-induced rise in public deficits that occurred before the government received higher revenues from oil and gas extraction.

Benchmark: In the benchmark simulation, real GDP growth is exogenously fixed and assumed to increase by 4 percent annually over the period 1997–2005, while the growth rate of labor productivity is calibrated for each year so as to keep growth constant over time. This implies steadily increasing labor productivity growth over the whole simulation period. Yet, the assumption that productivity growth is only labor-augmenting is not appropriate for Bolivia. We therefore assumed a balanced growth path along which capital per worker, measured in efficiency units, remains constant over time, and calibrated the growth rate of capital productivity, which keeps the capital–labor ratio constant. At given labor growth rates and given capital accumulation rates, this implies increasing capital productivity at a decreasing rate over the total simulation period.[19]

The most striking distributional result of the benchmark simulation is the lack of significant progress with regard to poverty reduction despite relatively high

[19]In the policy simulations discussed below, these calibrated productivity parameters are kept constant, and the growth rate of GDP and the capital–labor ratio are allowed to vary endogenously.

growth rates of 4 percent. This is largely the result of rural–urban migration, which increases the supply of urban unskilled labor, thereby depressing wages and increasing the urban wage differential between skilled and unskilled workers (Appendix 8). As a result, urban inequality rises while poverty stays constant (Table 6). At the same time, migration reduces the supply of unskilled labor in rural areas and thereby increases wages. Together with increasing land rental rates, higher wages for rural unskilled workers raise the mixed income earned in agriculture (agricultural profits in Appendix 8) and slightly reduce poverty and income inequality in rural areas (Table 6). At the national level, both the incidence of poverty (P0) and the poverty gap (P1) hardly change over the period under consideration.

Gas Shock: Given that our CGE model does not allow for multiplier effects, it is not surprising that the foreign direct investment in gas exploration and the construction of pipelines is shown to have only a minor impact on aggregate economic activity. In the short run, the demand shock causes a steep rise in the price level, which even lowers real GDP, while over the medium run production capacity is slightly higher than in the base run.

The model can much more reliably capture the structural effects of the demand shock, which turn out to be sizeable. The investment boom induces a massive expansion of exploration, which clearly dominates the much less pronounced expansion of formal (pipeline) construction. As a result, the factors attracted into gas-related activities are predominantly formal capital and to a lesser extent skilled labor, exerting upward pressure on formal profits and skilled wages. Two secondary effects refine this picture. First, booming gas-related investment crowds out other investment goods, which are predominantly produced by heavy manufacturing as well as the formal and informal construction sector. Since these sectors make intensive use of unskilled labor, the respective wage is driven down. The contraction of informal construction lowers the informalization of the economy. Second, the rise in the price level, which at a fixed exchange rate implies a real appreciation of about 6 percent in the medium run, leads to a contraction of trade-oriented sectors such as heavy manufacturing, mining, and modern agriculture, whereas sectors with low trade shares and non-traded sectors tend to expand. Among the gaining sectors with low trade-orientation, informal activities figure prominently. They realize higher returns on capital and demand additional labor, in particular unskilled workers, thus raising the informal share of unskilled labor.

As shown in Table 5, the investment boom is on balance associated with higher (lower) wages for skilled (unskilled) labor, higher profits in the informal urban sectors, and an increasing informalization of urban production activities, as indicated by lower formal unskilled employment shares compared to the base run. The net result of the informalization and the rise in the wage gap on the one hand, and increasing informal profits on the other, is that aggregate indicators of urban poverty and inequality hardly change (Table 6). In addition, lower wages for unskilled workers reduce incentives to migrate from traditional agriculture. Nevertheless, agricultural per-capita income increases slightly as a result of higher prices for agricultural products, which in turn leads to a slight reduction of rural poverty.

TABLE 5

CGE Results for Link Variables (shocks compared to BaU)

	Agricultural Profits	Informal Profits	Unskilled Wage	Skilled Wage	Unskilled Formal Share	Skilled Formal Share
Gas shock						
2001	101.5	103.9	98.6	102.3	–0.91	–0.04
2005	103.8	108.4	105.4	109.2	–1.19	0.06
Gas shock plus transfers						
2001	107.5	104.8	97.9	103.2	–0.98	–0.15
2005	113.6	109.5	102.6	108.4	–1.40	–0.20

Note: The table shows percentage changes compared to the BaU for profits and wages. The differences in formal employment shares for unskilled and skilled labor are percentage point differences to the BaU.

Source: Authors' calculations.

TABLE 6

Poverty and Distributional Results (point differences to BaU)

	All			Urban			Rural		
Scenario	P0	P1	Theil	P0	P1	Theil	P0	P1	Theil
Initial									
1997	61.2	35.0	76.8	50.8	23.5	63.3	77.8	53.3	73.6
BaU									
2001	61.2	34.7	77.6	51.0	23.5	64.6	77.4	52.5	72.6
2005	60.8	34.1	78.2	50.8	23.2	65.4	76.7	51.5	71.8
Gas shock									
2001	–0.2	–0.4	–0.1	–0.1	–0.4	–0.1	–0.4	–0.3	0.0
2005	–2.3	–1.3	0.4	–3.0	–1.5	0.2	–1.3	–1.0	0.2
Gas shock plus transfers									
2001	–0.7	–0.8	–0.4	–0.6	–0.6	0.0	–0.8	–1.2	–1.1
2005	–2.6	–1.9	–0.5	–3.2	–1.5	0.0	–1.7	–2.4	–1.6

Source: Authors' calculations.

In contrast to the investment demand shock, the subsequent extraction of gas from new fields significantly raises real GDP growth to almost 6 percent on average over the period 2004–2005. A rise in the aggregate price level and a significant improvement of the government budget balance through additional revenues are among the other important macroeconomic consequences of the gas shock.

The growth process induced by the gas shock is not sectorally balanced. The primary and most pronounced effect is the expansion of oil & gas and oil refining, the main downstream activity. This drives up formal capital prices and skilled wages, as these sectors are capital and skilled labor intensive. Furthermore, the reduction of the budget deficit is reflected in markedly higher investment demand by the government, which benefits both formal and informal construction. Making intensive use of unskilled labor, the construction sectors drive up unskilled wages via increased labor demand. Since the informal construction sector is particularly unskilled–labor intensive, the share of unskilled workers employed in the informal sector goes up as a result of the construction boom. As in the case of the investment

shock, a real appreciation leads to a reallocation of resources from more to less trade-oriented sectors including most informal activities, which reinforces the informalization of the economy. The effect is, however, quantitatively less important than that running via investment in construction.

Increased demand for skilled labor causes the unskilled–skilled wage gap to increase. Again, this increase as well as the rising importance of lower-paid informal employment is compensated by increases in informal profits so that overall urban inequality remains largely unchanged. The significant poverty reduction appears to be entirely growth-induced. It is larger in urban areas, which directly benefit from higher gas extraction while rural areas benefit only indirectly from higher demand for agricultural products and a moderate rise in rural–urban migration. Even though the Theil Index barely changes within regions, the national income distribution slightly worsens as the income gains are biased towards urban households.

Gas Shock plus Transfers: A redistribution of royalties and other revenues from the public to private households has essentially two primary effects. First, it increases disposable household income, consumption and household savings. Second, it increases current public expenditures and therefore reduces public savings. This will have secondary effects on overall income, inequality and poverty. At given household marginal propensities to consume and to save, the redistribution leads to a restructuring of final demand from investment demand towards private consumption. This is because the fall in government investment is not fully offset by a rise in private investment. Lower investment means lower capital accumulation and thus lower growth compared to the isolated gas shock scenario. The reduction of investment demand is mostly felt in the construction sector, both formal and informal, which reduces its production by 15 and 20 percent in 2001 and 2005, respectively. By the same reasoning as above, this leads to lower wages for unskilled labor and a lower informal share among unskilled workers. The latter effect is, however, offset by increased labor demand from all other informal sectors, which expand their production in response to a real appreciation caused by the expansionary government policy.

Regarding the overall changes in link variables, the redistribution policy hence appears to reinforce the results of the gas shock, with a widening wage gap, a slight increase in informal employment shares, as well as a further upturn in informal and agricultural profits. The corresponding poverty and distributional results, given in Table 6, only reflect the changes in labor market linkage variables. The direct effects of the transfers on disposable household income will be analyzed separately below.[20] In urban areas, both the headcount ratio and the poverty gap fell somewhat in 2001, driven by the rise in informal profits that offsets the negative effects of further increased informality and falling unskilled wages. Owing to considerably higher profits in traditional agriculture that result from increasing demand for agricultural products, distributional and poverty results look more favorable for rural areas.

[20]The 2001 household survey, which is used in the microsimulation model, contains the Bolivida transfer payments. Simulating the "targeting" implied by the Bolivida and other public transfers goes beyond the scope of this paper. We later illustrate the incidence of public transfer schemes by some exploratory simulations.

TABLE 7
Poverty and Distributional Impact of Increases in Public Transfers

Scenario	P0	P1	Theil	Resource Cost
			National	
Initial	61.2	35.0	76.8	
10% increase in public transfers	–0.7	–0.1	–0.1	0.97

Note: The resource cost refers to the increase in per capita income implied by the transfer.
Source: Authors' calculations.

To investigate the possible primary poverty and distributional impact of transfers, we conducted a stylized microsimulation in which we raised the transfers as observed in the household survey (PAYG pensions, Bonosol payments, and other social transfers) by 10 percent. Such a transfer policy would raise per capita incomes by about 1 percent, which can also be interpreted as the cost of increasing the transfers in the sense that it measures the resources the government transfers to households (Table 7). Strikingly, while P0 indicates some transfer-induced poverty reduction, P1 does not. This can easily be explained when looking at the growth incidence curve given in Appendix 9, which points to a very bad targeting, where the poorest 50 percent of the population benefit less than proportionately. The shape of the growth incidence curve also illustrates that aggregate indicators of inequality, such as the Theil Index that barely changes in this experiment, may well be misleading.

4. Concluding Remarks

In this paper, we combined a computable general equilibrium model with a microsimulation model to analyze numerically the short- to medium-run impact of Bolivia's booming gas sector on poverty and income distribution. This approach accounts for major transmission mechanisms through which the gas boom affects the distribution of income. It captures microeconomic determinants of distributional change such as the occupational choices between formal and informal employment and the corresponding changes in earnings at the individual level, as well as macroeconomic and sectoral determinants such as relative factor prices, rural–urban migration and informalization of production and employment. By focusing on poverty and distributional effects and by distinguishing informal and formal activities, our analysis adds a new perspective to the existing literature, which largely consists of macroeconomic studies based on the dichotomy between tradable and non-tradable sectors.

Our simulation results suggest that the gas boom and the expansion of public transfers have both unequalizing and equalizing distributional impacts that tend to offset each other. As net distributional change is limited, growth generated by the boom also reduces poverty and the boom hence does not completely bypass the poorer parts of the Bolivian population. Poverty reduction with little distributional change can be observed despite increasing informality. Using stylized microsimulation experiments, we illustrate that lower formal employment can lead to a significant rise in urban poverty and that the very poor are affected most by

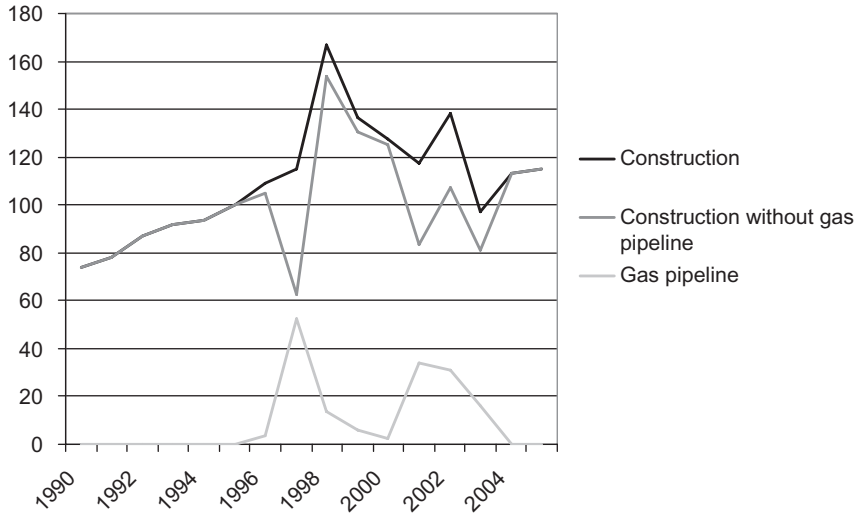
increasing informality. Yet, considerable overall increases in informal profits compensate this possible negative impact. Informalization and increasing informal rofits during the investment boom mainly result from contractions of investment good and trade-oriented sectors (cost-push). When gas exports pick up, demand for informally produced non-tradables increases (demand-pull) and formal sectors are hurt by real appreciation. The positive distributional impact of increased informal profits also masks the inequality-increasing impact of the widening of the unskilled–skilled wage gap that is particularly strong during the initial investment boom. Regarding the increase in public transfers, the government's redistribution policy is largely ineffective in reducing poverty as it is poorly targeted. The indirect effects of increased public transfers tend to reinforce the informalization process and hence the distributional and poverty impacts of the gas boom. In addition, the resulting lower investment leads to lower overall economic growth.[21]

If the increases in informal profits compensate the potentially negative poverty effects of increased informality, why should we worry about the resource-boom induced structural change? Before we discuss this crucial question, we should stress that this paper examines the reallocation processes induced by a gas boom and their distributional consequences in a time horizon of approximately one decade. Yet, only in a longer time horizon, sectoral externalities might come into effect, which render this reallocation towards informal activities worrisome. We think there are good reasons to believe that a sectoral pattern of change characterized by specialization into certain non-tradables and informalization can permanently damage a country's development prospects, although concrete empirical evidence is scarce. Manufacturing sectors that contract considerably in the Bolivian case are widely viewed as exhibiting important learning by doing effects. In addition, informal sectors may exhibit important negative externalities, as employment is often unstable and employees are typically not covered by any kind of social insurance. Such precarious employment is likely to have negative effects on human capital accumulation. If this pessimism about the sectoral change is valid, Bolivia's natural gas abundance may be seen as a curse rather than a blessing, adding to the experience of many other resource-rich developing countries.[22] In particular, the case of Bolivia exemplifies the failure of governments to redistribute resource rents in a pro-poor manner. However, as argued most recently by Lederman and Maloney (2007), the relationship between resource abundance and low economic growth and little poverty reduction is not a law; rather, it presents a challenge to find appropriate policies to avoid the pitfalls. While designing a coherent strategy towards this end is extremely difficult, redistribution of resource rents could make a dent in poverty—if targeted effectively.

[21]In interpreting all these effects, one should not put too much emphasis on exact magnitudes as they tend to be highly sensitive to parameter values such as trade elasticities and model assumptions such as macro closures. Errors in national account and household data may further reduce the accurateness of simulated numbers.

[22]Sachs and Warner (1997) note with regard to larger positive externalities in manufacturing that this assumption "remains somewhat speculative." This assessment still holds today and also applies to possible negative externalities of informal employment. In light of increasing informalization in many Latin American economies the latter may constitute an interesting area for future research.

Appendix 1: The Construction Sector, 1995 = 100



Source: INE (www.ine.gov.bo, 2005).

Appendix 2: Use of Survey Data in the Construction of the SAM

The SAM is based on national accounts data including an input–output table for 2000 provided by UDAPE. This macro SAM, in particular the functional income distribution, is then adjusted and extended using information from the household survey data. More specifically, the micro data is used to split intermediate input and factor use between formal and informal sectors. The original Bolivian input–output table reports value added by formal capital, labor and mixed (or self-employment) income. For each sector with a significant portion of informal employment, we split the sum of labor and mixed income value added into formal and informal components using the sum of individual income from employment reported in the survey—excluding formal capital. This implies that employment income from the survey is assumed not to include any formal capital income component, which seems a reasonable assumption in the Bolivian context. For informal sectors, we then assume relatively low degrees of capital intensity of 30, 36, and 46 percent (see Table 1). We also assume that formal sectors use intermediate inputs more intensively, an assumption that is borne out by the micro data (the survey reports gross and net income reported by formal and informal entrepreneurs, the difference of which we can compare across formal and informal activities). We implement the latter assumption by restricting the use of some formal inputs, for example those purchased from formal service sectors, to formal activities. A final important piece of information on factors markets, sectoral employment, is taken from the survey. The sectoral employment levels are used to calculate the sectoral wage gaps of the SAM shown in Table 2, a procedure that reveals some data source inconsistencies but still produces a reasonable representation of the micro-level wage structure. Furthermore, the household

sector of the SAM is also modified according to household survey information as explained in the main text. Together, these steps allow us to achieve a relatively high degree of consistency between the SAM to which the macro model is calibrated and the household survey data used for the microsimulation. The SAM is available from the authors upon request.

Appendix 3: Labels for Sectors

TradAgr	Traditional agriculture
ModAgr	Modern agriculture
ForFis	Forestry, Fishing
OilGas	Crude oil and natural gas
Exploration	Oil and gas exploration activities
FoodPro	Food processing
OthLiMan	Other light manufacturing
Chem	Chemicals
OilRef	Oil Refinery
Min	Minerals (non- and proc.)
HeavMan	Heavy manufacturing
EleGasWat	Electricity, gas, water
Const	Construction
Trade	Trade
Trans	Transport
CommFinBus	Communication, financial and business services
RealEst	Real Estate
SocPerServ	Social and personal services
HotRest	Hotels and restaurants
TradeDomS	Trade and domestic services
PubServ	Public services

Appendix 4: Estimation Results for the Choice Models

	Dependent Variable		
Explanatory Variables	Head's Choice	Spouse's Choice	Others' Choice
Education	–0.201 (0.036)***	–0.323 (0.062)***	–0.231 (0.067)***
Education squared	0.019 (0.002)***	0.062 (0.003)***	0.024 (0.004)***
Experience	–0.013 (0.003)***	–0.012 (0.008)	0.005 (0.009)
Female dummy	–1.112 (0.098)***	–0.887 (0.314)***	–0.740 (0.220)***
Formal employment share in province	4.530 (0.572)***	1.662 (1.090)	3.004 (1.117)***
Indigenous dummy		–0.616 (0.202)***	
Number of children under 10		0.412 (0.182)**	0.113 (0.071)
Interaction female × number of children		–0.353 (0.193)*	–0.219 (0.108)**
Head's formal sector wage		0.203 (0.024)***	0.137 (0.024)***
Widow dummy			0.508 (0.532)
Beni dummy		0.552 (0.271)**	
Pando dummy		0.817 (0.410)**	
Constant	–1.553 (0.346)***	–0.871 (0.683)	–2.383 (0.648)***
Observations	3,385	1,140	1,102
Pseudo R^2	0.16	0.26	0.19

Notes: Robust standard errors in parentheses.
Significant at *10%, **5%; ***1% level.
Source: Authors' calculations.

Appendix 5: Estimation Results for the Wage and Profit Equations

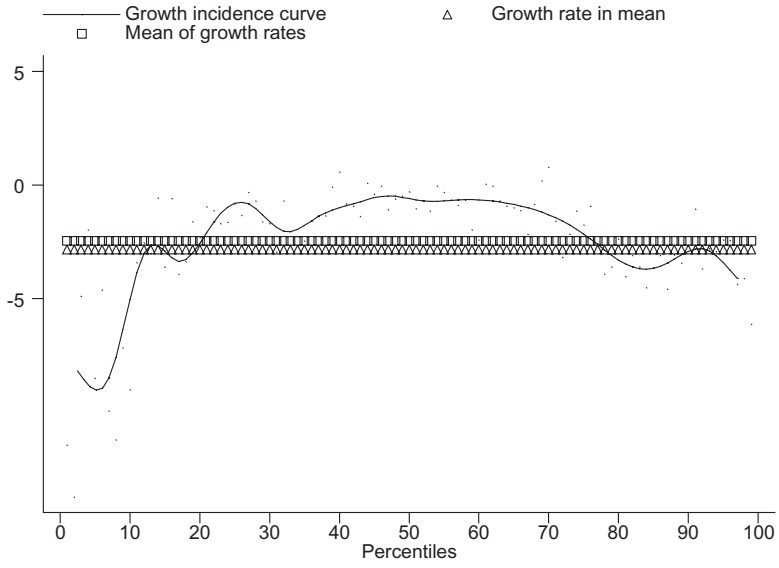
	Dependent Variable		
Explanatory Variables	Formal Unskilled Wages	Formal Skilled Wages	Informal Profits
Education	0.084*** (0.009)	0.120*** (0.022)	
Experience	0.051*** (0.005)	0.056*** (0.007)	
Experience squared	–0.001*** (0.000)	–0.001*** (0.000)	
Female dummy	–0.627*** (0.055)	–0.330*** (0.051)	
Potosi dummy	–0.182** (0.084)	–0.177* (0.095)	
Tarija dummy	0.307*** (0.085)	0.172* (0.096)	
Santa Cruz	0.193*** (0.070)	0.249*** (0.068)	0.157*** (0.055)
Beni dummy	0.374*** (0.078)	0.147** (0.075)	0.165** (0.075)
Pando dummy	0.000 (0.424)	0.201* (0.105)	0.823*** (0.084)
Inverse Mills ratio		–0.241* (0.142)	
Avg. education			0.059*** (0.007)
Avg. experience			0.038*** (0.004)
Avg. experience squared			–0.001*** (0.000)
Number of females			–0.602*** (0.043)
Number of enterprise members			1.332*** (0.066)
Constant	5.092 (0.112)***	4.792*** (0.355)	4.947 (0.102)***
Observations	1,357	1,407	1,905
R-squared	0.26	0.27	0.31

Notes: Robust standard errors in parentheses. Standard errors for the selection-corrected skilled wage equation are corrected for heteroscedasticity arising from the two-step procedure.

Significant at *10%, **5%; ***1% level.

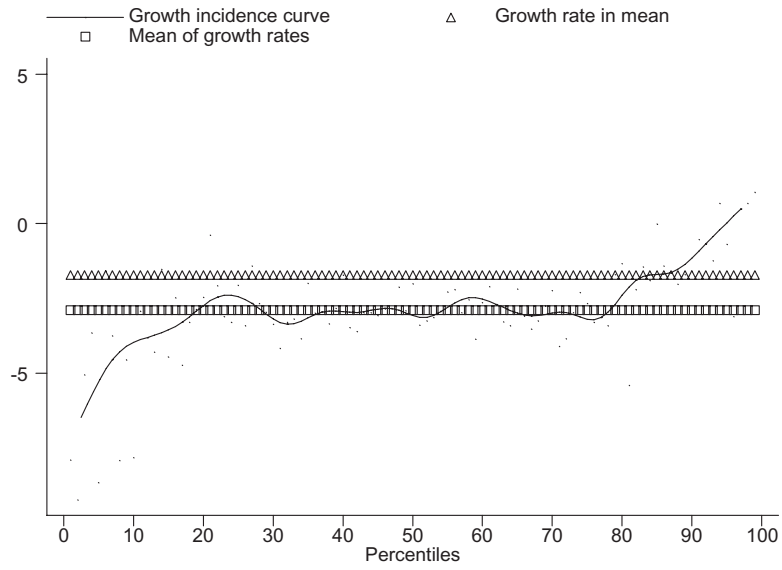
Source: Authors' calculations.

Appendix 6: Growth Incidence Curve, 5 Point Decline in Formal Employment for Unskilled Labor



Source: Authors' calculations.

Appendix 7: Growth Incidence Curve, 5 Point Decline in Formal Employment for Skilled Labor



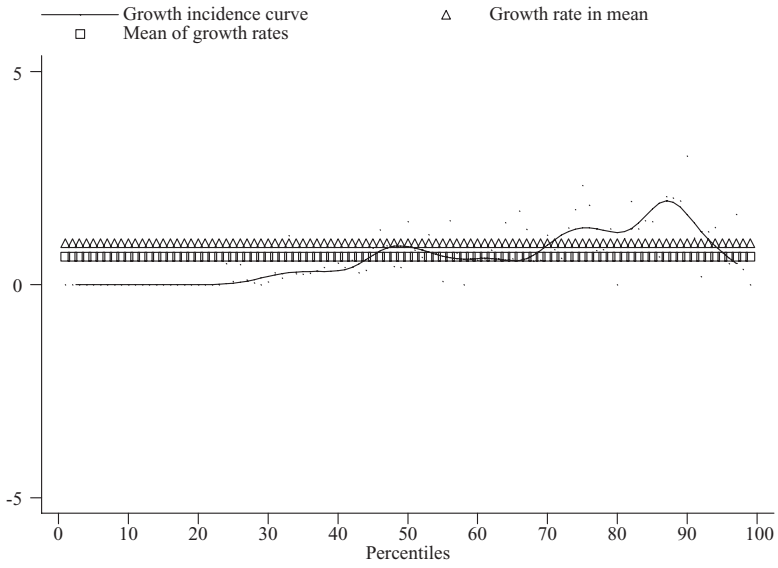
Source: Authors' calculations.

Appendix 8: Business as Usual (BaU) Scenario

Variable	1997	2001	2005
GDP growth rate		4.00	4.00
Price level	1.00	0.97	0.94
Growth rate of capital productivity		1.45	1.15
Growth rate of labor productivity		1.56	1.61
Labor demand			
Skilled labor	1.00	1.11	1.23
Rural unskilled labor	1.00	1.06	1.13
Urban unskilled labor	1.00	1.16	1.34
Migration	1.00	0.87	0.78
Capital demand			
Formal capital	1.00	1.11	1.25
Informal capital	1.00	1.12	1.27
Link variables			
Agricultural profits	1.00	1.06	1.13
Informal profits	1.00	1.00	1.00
Unskilled wage	1.00	0.97	0.97
Skilled wage	1.00	1.03	1.07
Formal share unskilled	0.38	0.38	0.39
Formal share skilled	0.72	0.71	0.71

Source: Authors' calculations.

Appendix 9: Growth Incidence Curve, 10 Percent Increase in Transfers to All Households



Source: Authors' calculations.

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