

Reduction of global poverty through sector-specific investment

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Abstract

This paper explores links between industrial investment in developing countries and its effect on global poverty in order to identify such a pattern of investment that reduces global poverty most for a given amount of investment available.

The link between investment and poverty is established in two steps as a link between investment and global price changes with the use of the GTAP model and data, and a link between price changes and global poverty using household survey data.

The results suggest that an optimal investment option for one billion US dollars, at least from the point of view of poverty reduction, is to invest it primarily to the countries of Sub-Saharan Africa (namely Congo, Ethiopia and Nigeria) into the food producing and processing sectors. Such an investment is expected to move 9.4 million out of poverty, primarily in Sub-Saharan Africa.

The paper further shows that if the amount of available investment were greater, its optimal allocation would change and it would include investments into other regions and industrial sectors. Even though it appears that the rate of poverty reduction through investment falls with greater investment, it appears possible to remove poverty by 300 million people—or about 25% of total world's poverty—through a well directed investment of 1,000 billion US dollars.

Introduction

If we had one billion dollars available to our free disposal and desire to use the money to fight poverty, what should we do? We would have two options: we could either transfer the money to the poor directly, thus immediately increasing their welfare, or we could invest the resources in the poor regions for the sake of their future development and welfare gains. Handing the money to the poor may bring immediate results, but it is an ephemeral option. It is also largely an irrational option under a belief that the poor regions are capable of sustainable development, in which case investment is a preferred option.

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With optimal investment in mind, we would have a choice of a portfolio of investment from diverse sectors, such as education, healthcare, infrastructure, government, and industry. Each of these options is associated with a different set of outcomes, and in order to invest rationally, we should choose that option whose results come closest to our goal of poverty reduction. Unfortunately, despite a host of research done on this subject we remain unable to identify the most optimal use for an additional dollar invested into poverty reduction.

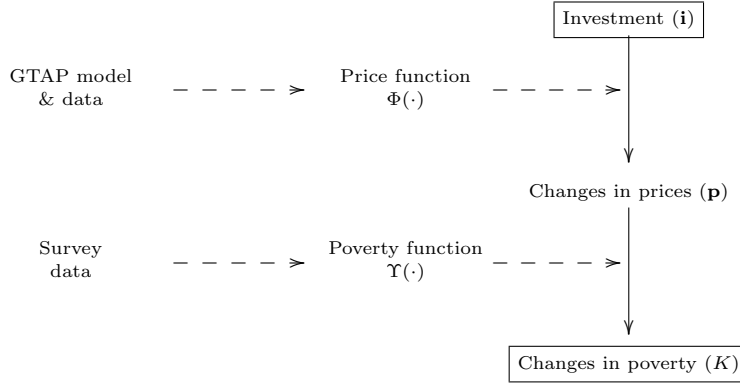
The goal of this paper is to contribute to the current state of knowledge by exploring a global link between investment and poverty reduction. Acknowledging the complexity of this link due to a wide range of investment possibilities, we restrict ourselves to the exploration of a small subset of investment options, namely investment into industrial production. Hence, in this work, we attempt to identify a pattern of investment into the production sectors of the developing countries that would result into the greatest poverty reduction worldwide, subject to the limit on the amount of investment.

There appear three pieces of knowledge necessary to answer our question. Initially, we would have to understand the global effects of each type of investment on the prices and incomes faced by the people of all countries. Then we would need to understand how these new prices and incomes translate into the welfare of the poor. Finally, we would need to be able to place a price tag on each investment and find such a mix of investment that would produce the greatest reduction in poverty. Even though none of these partial questions is completely clear to us at this point either, we have some restricted means of answering them at a varying degree of completeness.

In describing the link between investment and prices, we rely on the the existing global production and trade models that capture in the best way currently possible relationships among economic variables in a number of countries. More specifically, we use the GTAP model of Hertel (1997) that captures economic links among eighty-seven regions and fifty-seven production sectors. We use this model and its extensive database (Dimaranan and McDougall, 2002) to define parsimoniously a relationship between investment and prices among all developing regions. Making a further step towards a complete coverage of all developing countries in the world, we extrapolate the investment-price links of the GTAP model to those regions that are not directly identified in the model.

For relating poverty to the changes in prices and incomes, we turn to the extensive household survey data available for fifteen developing countries that have been analyzed by Ivanic (2002). Using the information on the distribution and structure of household incomes contained in those surveys and the consumption information obtained from the International Comparison Project (1996), we derive a globally valid relationship between the changes in incomes and prices, and the change in poverty.

We build our analytical framework of identifying optimal investment allocation by pressing the derived relationships among



Scheme 1: Overview of the method

investment, prices, incomes and poverty to work in an math program that allocates investment in such a way that produces the greatest poverty reduction subject to the limit on the amount of investment. By making a simplifying assumption that the cost of investment is equal to the value of production it adds, and using the extensive World Bank data (Ross-Larson and de Coquereaumont, 2001) on the levels of poverty world-wide—extrapolated to those countries where no data are available—we make our framework complete and capable of identifying combinations of sectors-regions in which investment would have a greater effect in reducing poverty.

Method

The method of this paper builds on the methods and data sources commonly used in economic policy analysis. Scheme 1 shows the main points of this method along with all required data. A CGE model (GTAP) with output-input data defines a price function $\Phi(\mathbf{i})$ that maps investment $\mathbf{i}$ to the changes in prices and incomes (factor prices) $\mathbf{p}$. An econometric model of poverty change based on detailed household survey data describes the effect of the price changes on poverty K through a poverty function $\Upsilon(\mathbf{p})$. Having established a complete link $K = \Upsilon(\Phi(\mathbf{x}))$ between investment $\mathbf{i}$ and poverty K , we then determine an optimal allocation of a given investment budget B with the goal of the greatest reduction in poverty. For that purpose, we lay out an optimization problem in which we lower poverty subject to the constraint of the size of the investment.

Price function: CGE link between investment and global changes in prices and incomes

Our method of linking productivity changes to prices and incomes is based on expressing price and income ($\mathbf{p}$) changes through a summary function of investment ($\mathbf{i}$) based on an actual CGE model. We base our derivation of the summary function on our understanding of the model, the GTAP model in our case, of as a special kind of function—indeed a very

bulky function—that maps a vector of exogenous variables, investment ($\mathbf{i}$) to a vector of endogenous ones, prices ($\mathbf{p}$). This fact could be captured by a simple equation $\mathbf{p} = GTAP(\mathbf{i})$.

Naturally, a proper definition of this function in terms of parameters is often infeasible or perhaps impossible as this would require a lengthy back-solving exercise in which a model is reduced into a single equation. Even if a proper evaluation of this equation is not possible, a reasonable approximation of it can be acceptable and useful. In the case of the GTAP model, such an approximation is the linear approximation of the percent changes in variables. Under such a definition of a model, the equation can be rewritten in linear form as a product of a parameter matrix M and exogenous variables as $\hat{\mathbf{p}} = M \times \mathbf{i}$. Note that this equation has no intercept, because in the percentage change, linear form of the model we require that a zero endogenous and exogenous change be a solution of the model, i.e. $\mathbf{0} = M \times \mathbf{0}$.

Finally, we need to translate the amount of investment into a percentage change variable. Based on the nature of the GTAP model, we assume that an investment i translates into such a productivity change $\hat{q}$ that is equal to the amount of investment relative to the current production level q in the respective sector. Thus a vector of investments $\mathbf{i}$ produces a change in production $\hat{q} = \frac{i}{q}$. This definition implicitly defines the cost of investment that produces a given change in productivity, which is very useful in our practical linking of the cost of investment to its price and income effects. Thus the price function of investment used in our work is $\hat{\mathbf{p}} = M \times \hat{\mathbf{q}}$ where $\hat{q}_i = \frac{i_i}{q_i}$.

Poverty function: Econometric model of poverty change

The objective of this section is to estimate a global relationship between prices and incomes (factor price) $\mathbf{p}$ and poverty K through a price function $\Upsilon(\cdot)$ so that $K = \Upsilon(\mathbf{p})$. This estimation is based on detailed data on factor earnings contained in household surveys of fifteen developing countries as reported by Ivanic (2002). Because of the relative nature of both poverty and prices, the poverty function is estimated as a second order approximation of the percent change form $\hat{K} = \sum_i \alpha_i \hat{p}_i + \sum_{i \leq j} \beta_{ij} \hat{p}_i \hat{p}_j$. Because a homogeneous change in all prices should produce no change in poverty, we impose the following homogeneity restrictions on the parameters: $\sum_i \alpha_i = 0$ and $\sum_i \sum_j \beta_{ij} = 0$.

We estimate this function for six prices and five incomes (factor prices) as used in the work of Hertel *et al.* (2003) on trade liberalization and poverty. The included goods are: grains, livestock, other food, durables, non-durables, and services. On the income side we include the returns to the following factors: land, capital, unskilled labor, skilled labor and transfers.

To estimate this regression, we have created a random sample of 60,000 observations of changes in prices and incomes drawn randomly from a uniform distribution. We have deflated these prices by CPI change implied by them and fed them into a household model to calculate poverty changes based on observed income distributions and an AIDADS consumer

demand system based on the work of Rimmer and Powell (1992). This demand system was calibrated to each of the fifteen countries included in our household model based on the work of Cranfield *et al.* (2003). The representation of the consumption behavior in the household model by a demand system is not crucial to our framework, but a result of the unavailability of expenditure data in the household surveys. If a new set of household surveys contains enough detail in consumption, this demand forecasting could be avoided.

Derivation of an optimal investment pattern

In order to derive an vector of investment $\mathbf{i}$, we define and solve a math program that incorporates our objective of maximum reduction in world poverty K while constraining ourselves to a budget constraint B , equal to one billion US dollars for the sake of an exercise. The program can be written as $\min_{\mathbf{i}} K = \Upsilon(\Phi(\mathbf{i}))$, subject to $\sum_j i_j \leq B$, $\mathbf{i} \geq 0$ where poverty K is defined by a poverty function $\Upsilon(\cdot)$ that takes as its argument the price changes defined by the price function $\Phi(\cdot)$ of an investment vector $\mathbf{i}$. B defines the budget constraint on the amount of investment.

Estimation of price functions and poverty rates for regions without available data

There are 178 developing countries in the world and they encompass 5.1 billion of people. In order to proceed with our method as envisaged, we would need to derive price functions and current poverty estimates for each of them. Unfortunately, we live in a world of incomplete information: the GTAP data that we use to derive price functions cover only eighty-seven regions that coincide with even a smaller number of thirty-five developing countries and cover 74% of the developing world population. On the side of poverty estimates, the World Bank Development Report includes poverty estimates for sixty-one developing regions that contain 83% of the developing world population. Thus, in terms of our methodology, we have complete information for 62%, partial information for 34% and no information for just 4% of the relevant population of the developing world. We believe that this data coverage is excellent considering the innovative nature of our work.

In order to provide complete results, we have extrapolated missing information for each developing region in the following way. In the cases of missing price functions for a given country, we used the price function derived for the GTAP region that contains it and weighted its terms by the relative size of the GDP in the relevant region. Thus, for example, in order to create a price function for Ecuador, which is not an independent region in GTAP, we used the Andean region—called “XAP” in GTAP—price function and adjusted it for Ecuador so that every effect of Ecuador on other countries would only by 69% of the effect, because Ecuador’s GDP is that share of the region’s GDP. The own country effects, however, remained unchanged, following the assumption that all countries inside a single GTAP region are homogenous.

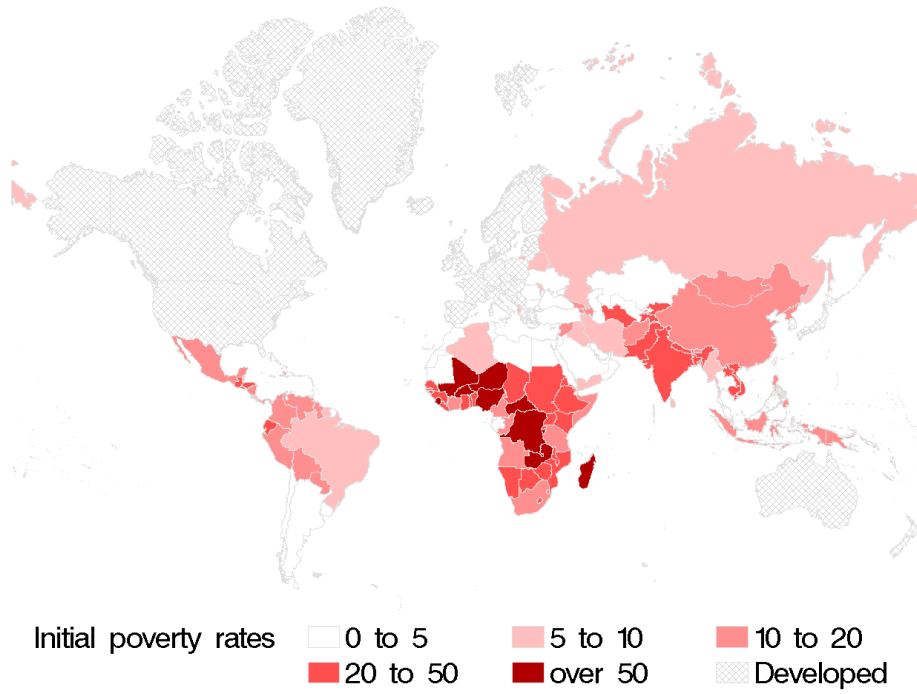


Figure 1: Observed and estimated poverty rates around the developing world

In order to extrapolate poverty rates for the missing regions, we have used a regression of the country poverty rate on per capita GDP, and used this predicted relationship to estimate poverty rates in the countries where no World Bank estimates were available. The observed and estimated poverty rates are summarized in Figure 3.

Results

Effects of output change on global prices

In order to understand the effect of the change in output on poverty we need to answer the question of how these changes in output translate into the changes in global prices and incomes. In order to do that, we use a linear version of the GTAP model to calculate the functions that link the changes in output in each country's sector to the change in each commodity price and income in all developing countries. Because the model is linear with a trivial solution of a zero vector, any vector of endogenous variables, prices $\mathbf{p}$, can be written as a linear combination of the vector of exogenous variables, investment $\mathbf{i}$, and a matrix of coefficients M that are determined by the underlying model, so that $\mathbf{p} = M \times \mathbf{i}$.

Naturally, matrix M is initially unknown but can be easily retrieved by obtaining a sufficient number of observations of $\mathbf{i}$ along with the resulting $\mathbf{p}$ that just define matrix M and the number of necessary runs is equal to the number of exogenous variables. In our case we used a model that contained fifty-one developing regions and ten commodities, making it necessary to run the model 510 times. The version of the model we used was the standard GTAP model in a long-run closure and

		Investments										
		Staple crops	Food crops	Cash crops	Livestock	Staple processed	Other proc food	Proc meat	Non-durables	Durables	Services	Capital goods
Price changes	Staple crops	-1.2	-0.1		-0.1	-0.1			0.6	0.5	0.6	0.2
	Food crops	-0.1	-1.3		-0.1				0.7	0.5	0.6	0.2
	Cash crops	-0.1	-0.1	-1.1	-0.1				0.6	0.5	0.5	0.2
	Livestock	-0.1	-0.1		-1.3				0.7	0.5	0.6	0.2
	Staple processed	-0.4	-0.1		-0.1	-1.1	-0.1		0.5	0.5	0.3	0.2
	Other proc food	-0.1	-0.1	-0.1	-0.1		-1.2		0.5	0.5	0.3	0.2
	Proc meat				-0.6			-1.1	0.6	0.5	0.4	0.2
	Non-durables								-0.9	0.4	0.1	0.1
	Durables								0.3	-0.9	0.1	0.1
	Services								0.6	0.5	-0.8	0.2
	Capital goods								0.3	0.1	-0.4	-0.9
Income changes	Land	-0.5	-0.7	-0.2	-0.7	-0.1	-0.1		1	0.1	1.7	0.2
	UnSkLab			0.1	0.1		0.1		1	0.8	0.7	0.2
	Skilled labor	0.1	0.1	0.1	0.1		0.1		1.1	0.8	0.7	0.3
	Capital	0.1	0.1	0.1	0.1		0.1		1	0.8	0.7	0.2
	Natural resources	0.1	0.1		-0.8	0.1	0.1		1.1	0.2	1.3	0.1

Table 1: Average effects of productivity changes on prices and incomes

including ten basic production sectors. The retrieved summary matrix of the productivity effects on poverty provides valuable information on various important questions related to an optimal poverty-focused investment option. The most important question for which the matrix provides an answers is the identification of the investments with the greatest price and income effects. Because we will later translate these price changes into poverty changes, this information is indeed one of the major pillars of this work.

It is neither feasible nor useful to print the retrieved matrix M here (the matrix is 816×561). On the other hand, certain summary statistics of this matrix are useful. The first one is the average relationship between the output change on prices throughout all fifty-one developing regions shown in Table 1. The table shows average changes in prices following a change in output throughout all developing countries. As expected, increasing productivity in a particular commodity has generally a strongly negative effect on its price even though in some cases this effect seems to be more amplified than in others. Thus an increase in productivity in services produces a smaller price reduction than an identical change in productivity of food crops or livestock. Other than affecting its own prices, productivity changes also affect other commodity prices, with the signs roughly corresponding to the complement/substitute split among the commodities.

Table 1 also tells us a lot about the effects of the investment on various types of income. The most significant relationships shown in the table are of two types. The first one is the negative effect in increased productivity of food-related commodities on their prices and, in turn, on returns to the immobile land. The second type of relationship is the positive relationship between higher productivity in non-food items and all other factors.

In addition to finding exact investment-price relationship, the summary matrix also permits us to how much of the change

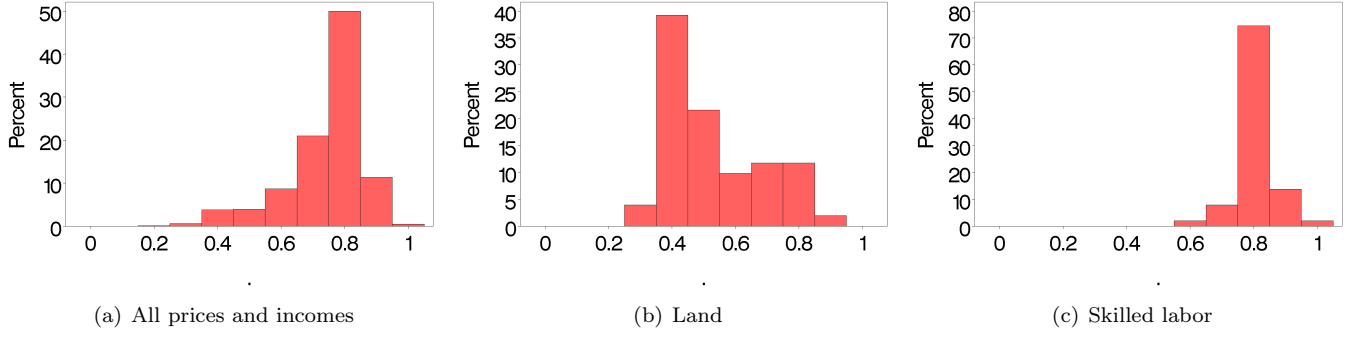


Figure 2: Distribution of the share of home country effect on the changes in incomes and prices

in productivity remains contained within the country of origin and how much it affects other countries' prices. Knowing this is extremely important as it would affect the nature of the appropriate investment action. If we found out that the spill-over effect is insignificant, and optimal investment question would reduce itself to a number of country-specific investment questions. If, on the other hand, we would find out that an investment decision in one country would have a significant spill-over effect over its borders, we would be obliged to view optimal investment questions as essentially global.

Figure 2(a) plots the distribution of the portion of the investment effect on the changes in prices and incomes that is due to its own investment. The figure suggests that even though the home investment decision is dominant—in most prices and incomes over 75% of the change is due to it—the effect of other countries is considerable. In addition to that, great variation in the amount of spill-over effects exists. Figure 2(b) shows that in the case of land returns, these are affected far more greatly by the extra-country investments, while on the other hand, skilled labor wages show very strict dependence on the home investment as shown in Figure 2(c).

Effects of price and income changes on poverty

Table 2 presents the parameter estimates, standard errors, and the probability associated with the econometric estimation. Observations exceeding a 30% change in poverty were considered outliers due to spurious correlation of independent variables, and thus removed from the estimation. This result in a loss of 4.3% of the observations, resulting in a total number of observations used of 57,364. The regression produces an R-square of 0.685, which is a good indication of the plausibility of reproducing poverty changes by changes in prices. This is relevant considering the cross-section nature of the data produced. Given the diversity in the geographical representation of the sample countries, we believe this is evidence of the global nature of the obtained estimates.

The linear terms are highly significant and they report the expected sign. Thus, an increase in the price of factors of production decreases the poverty level, and an increase in commodity prices increases poverty. Judging from the magnitude

	Linear term	Quadratic terms										
		Capital	Skil. labor	Unskl. lab.	Land	Transfers	Grains	Livestock	Other food	Nondurab.	Durables	Services
Capital	-0.6712	0.0035							0.01 significance			
Skil. labor	-0.122	0.0009	-0.0001						0.05 significance			
Unskl. lab.	-0.3437	0.0027	0.0006	0.0002								
Land	-0.0447	-0.0002	0.0002	0.0001	0.0006							
Transfers	-0.0763	0.001	0.0007	0.0006	-0.0003	-0.0004						
Grains	0.1779	0.0008	-0.0012	-0.0013	-0.0008	0.0016	-0.0022					
livestock	0.1483	-0.0009	-0.0006	0.0005	-0.0002	0.0012	-0.0012	-0.0009				
othfood	0.179	-0.0012	-0.0011	0.0003	0.0006	0.001	-0.0038	-0.0018	-0.0021			
nondur	0.2829	-0.0021	-0.0005	0.0001	0.0002	0.0015	0.0007	0.0015	0.0002	0.0027		
durables	0.1207	-0.0002	-0.0005	0.0014	0.0001	0.0009	-0.0009	-0.0013	-0.0009	0.0023	-0.0006	
Services	0.349	-0.0021	-0.0015	-0.0002	0	0.0018	-0.0024	-0.0007	-0.0022	0.0054	0.0007	-0.0006

Table 2: The estimated values of linear and quadratic terms (shading denominates significant values)

	Africa	Asia	Latin America	Total
Staple crops	227	6	2	234
Food crops	0	0	0	0
Cash crops	189	0	0	189
Livestock	99	0	0	99
Staple processed	49	0	0	49
Other proc food	76	0	0	76
Proc meat	73	0	0	73
Non-durables	104	0	0	104
Durables	176	0	0	176
Services	0	0	0	0
Capital goods	0	0	0	0
Total	992	6	2	1000

Table 3: Optimal distribution of a billion US dollar investment into sectors and regions

of the estimates Capital affects most the poverty level, where an increase in one percent in the price of capital used in production decreases the percentage change in poverty by 0.671. The effect of Unskilled labor follows in magnitude, and in a lesser degree skilled labor, transfers, and land. The insight here is that factor shares are fairly homogeneous for poor households globally. Commodity prices have a fairly homogeneous effect on poverty, ranging from 0.121 for durables to 0.349 for services.

Relationship between amount of investment and poverty

Result of a one billion investment

Our optimization simulation in which we tried to allocate one billion of US dollars to produce the greatest poverty reduction has resulted in the following pattern shown in Figure 3.

The composition of the optimal investment would be as Table 3 shows. According to it, the vast majority of the investment should be directed to the most poverty-struck central Africa (Congo, Ethiopia, Nigeria) and, more specifically, into the staple food and cash crop production.

The effect of the investment, distributed as shown in Table 3 would result in poverty fall not only in the countries where the investment is placed, but through spillover effects described earlier, some benefits would carry through to other regions,

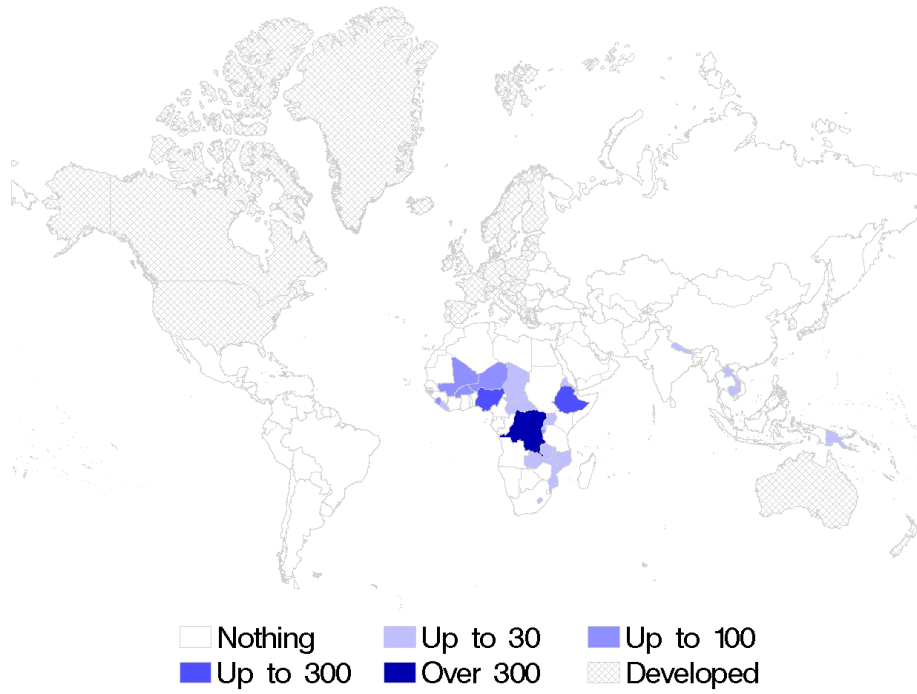


Figure 3: An investment of a billion of US dollars that would produce the greatest reduction in the world's poverty

covering almost all developing regions as shown in Figure 4. The total poverty reduction do to the one billion investment is predicted to be 9.4 million people, almost exclusively located in Sub-Saharan Africa.

Other issues: Questions you might have asked but never got an answer

In this paper we have laid out a framework for evaluating poverty effects of a constrained amount of industrial investment. Our framework is flexible, however, to shed some light on many other and more general questions arising with respect to investment for poverty reduction. These questions include the general relationship between the level of investment and poverty, as well as the question of its optimal destination with respect to the amount of investment. Because of the limited scope of this paper, we are unable to answer these questions fully. Nevertheless, we report some of our most interesting findings in this sections with the intention to stir more interest in this type of work.

Relationship between investment and poverty

We have used our math program to identify the change in poverty for various levels of investment and plotted the results in Figure 5. As expected, the relationship between investment and poverty reduction is monotonic and positive. Furthermore, it appears that the marginal cost of poverty reduction increases or, in other words, we would need increasingly more investment to lower poverty by the same number of people. We believe that this observation is caused by the fact that income distributions tend to be highly concave, thus making it more and more difficult to remove additional people from poverty. We are firmly

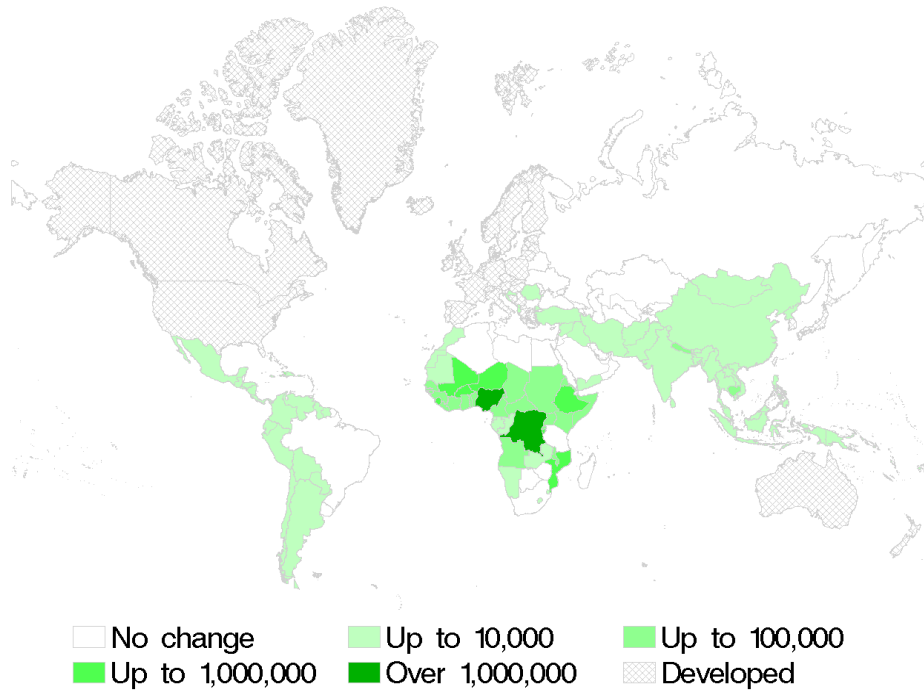


Figure 4: Change in world's poverty headcount as a result of an optimal one billion US dollar investment

convinced that this result is not caused by the linear and quadratic approximations the price and poverty functions in our framework, as the sizes of price and production changes are very small and lower than 20 percentage points even for the investment size of one trillion US dollars.

Composition of ideal investment

We have used our framework to identify the ideal composition of an investment aimed at poverty reduction with respect to the production sectors. Our results, summarized in Figure 6, suggest an interesting fact that the structure of an optimal investment varies greatly with its size. While the prime destination of a small investment should be the sector that processes staple food, it would include all other sectors including services if the size of investment grows sufficiently big.

The optimal regional destination of investment aimed at poverty reduction appears also dependent on its size, though less so. The solve optimal recipient of investments up to the size of one billion US dollars is Sub-Saharan Africa. Only if the amount of investment grows beyond this amount, does it become optimal to invest elsewhere, especially in South Asia.

Conclusion

Assessing the impact of investment on poverty at a global level is a gigantic task. The different regions-sector combinations as to maximize poverty reduction are obviously dependent on countries' particular characteristics. In addition, the lack of

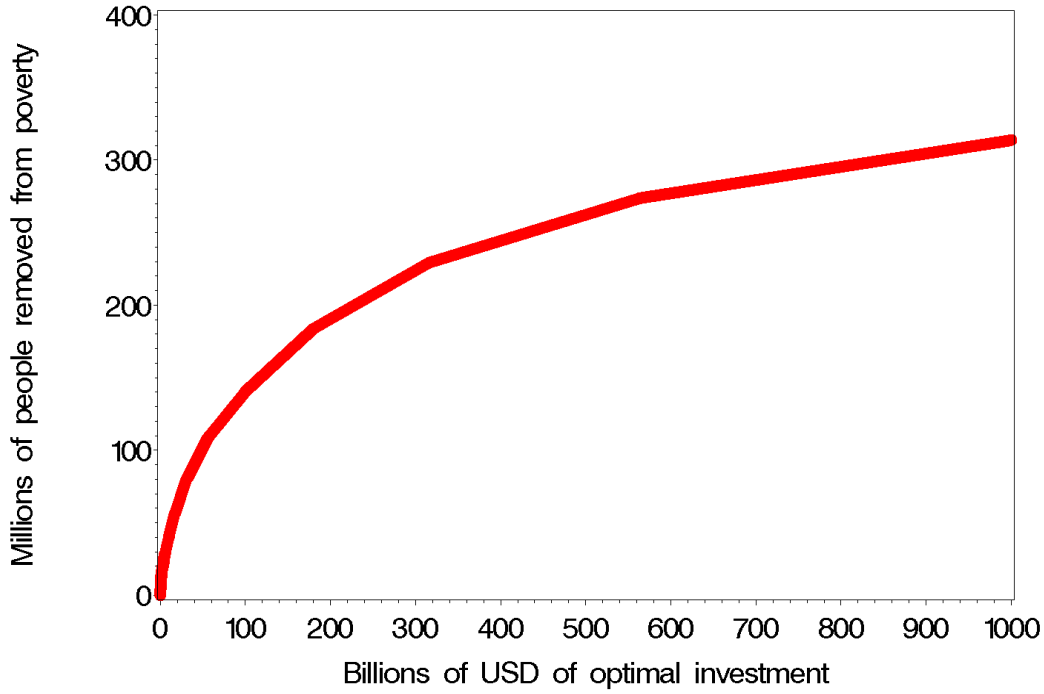


Figure 5: Effect of optimal investment on global poverty

market return value of basic human needed investments, such as health and education compounds the problem. If we were to limit this assessment to only a portfolio of investment in production of goods, the characterization of the link between investment and poverty reduction will still be a huge task as the lack of literature addressing this aspect signals.

So by proposing a way of characterizing this link, we believe this study is making a significant contribution to the poverty alleviation discussion, even by allowing us to put a price tag to poverty reduction. Probably the most relevant aspect of this characterization is its flexibility to accommodate improvements in data production, e.g. proliferation of detailed household surveys, and valuation of non commercial goods.

Our particular findings indicate that in order to maximize global poverty reduction, investments—in the range of one billion US dollars—should go to food production activities in Africa. We are able to show how the pattern of investment changes relative to the amount of investment. At the production level, shifting from cash crops with minimal investment to food production in the middle range of investment to a diversified portfolio of investment with considerable amounts. At the regional level, shifting from a full concentration in Africa for lower levels of investment to a more homogeneous distribution if a large sum of investment were to be available.

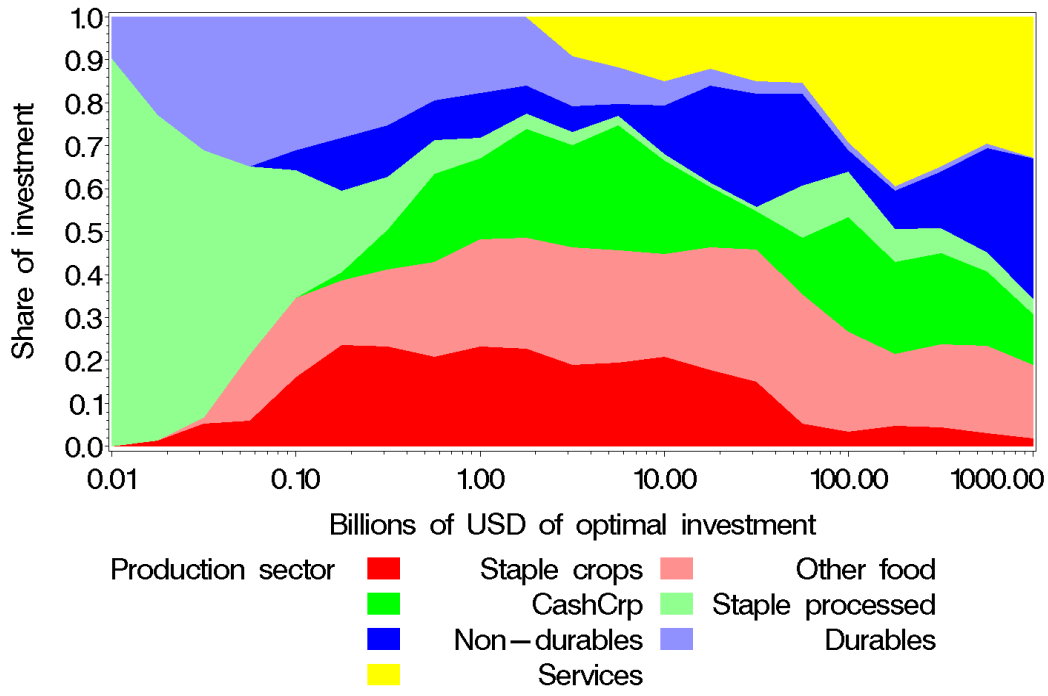


Figure 6: Optimal sectoral destination for a given level of investment

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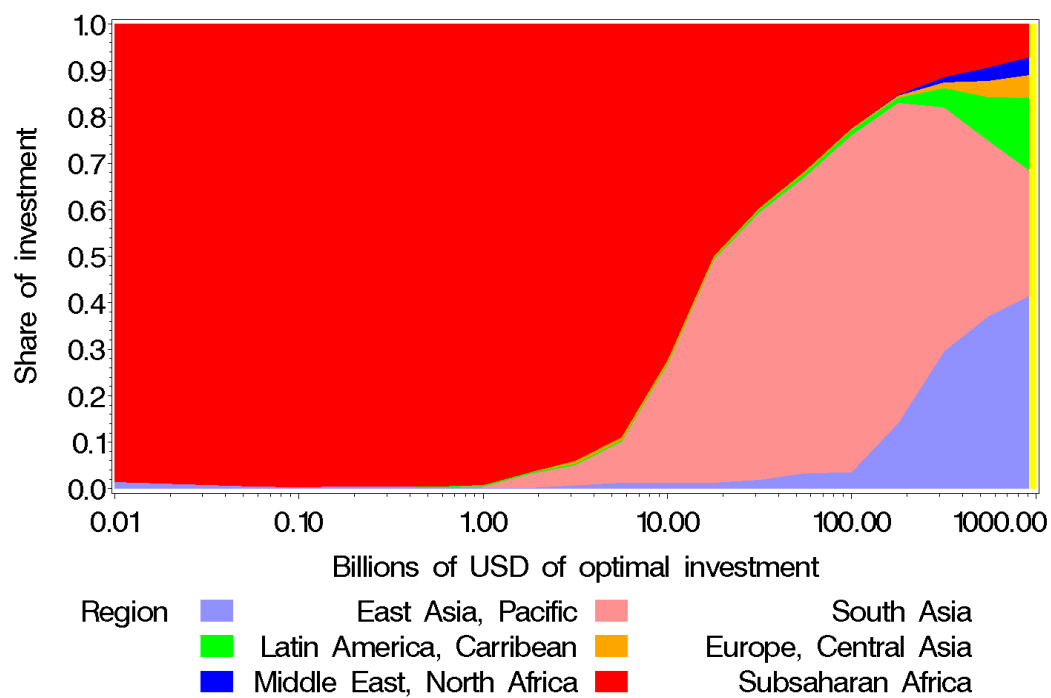


Figure 7: Optimal regional for a given level of investment