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Examining Beneficiation

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Abstract: Beneficiation, moving downstream, and promoting greater value added in natural resources are very common policy initiatives to stimulate new export sectors in developing countries, largely based on the premise that this is a natural and logical path for structural transformation. But upon closer examination, we find that very few countries that export raw materials also export their processed forms, or transition to greater processing. The quantitative analysis finds that broad factor intensities do a much better job of identifying patterns of production and structural transformation than forward linkages, which have an insignificant impact despite the fact that our data is biased against finding significant effects of factor intensities and towards finding significant effects of forward linkages. Moreover, the explanatory power of forward linkages is even smaller in sectors with high transport costs, and in sectors classified as primary products or raw materials, which are the most common targets of such policies. Finally, the results are the same even when only considering developed countries, meaning that colonial legacy inhibiting transitions to natural resource processing are not to blame. These results suggest that policies to promote greater downstream processing as an export promotion policy are misguided. Structural transformation favors sectors with similar technological requirements, factor intensities, and other requisite capabilities, not products connected in production chains. There is no reason for countries like South Africa to focus attention on beneficiation at the expense of policies that would allow other export sectors to emerge. This makes no sense conceptually, and is completely inconsistent with international experience. Quite simply, beneficiation is a bad policy paradigm.

Keywords: beneficiation, linkages, structural transformation

JEL Codes: F10, O10, O13

This paper is part of the CID South Africa Growth Initiative. This project is an initiative of the National Treasury of the Republic of South Africa within the government's Accelerated and Shared Growth Initiative (ASGI-SA), which seeks to consolidate the gains of post-transition economic stability and accelerate growth in order to create employment and improve the livelihoods of all South Africans. For more information and the entire series of papers, visit the project's web site at http://www.cid.harvard.edu/southafrica.

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DRAFT FOR DISCUSSION

Abstract: Beneficiation, moving downstream, and promoting greater value added in natural resources are very common policy initiatives to stimulate new export sectors in developing countries, largely based on the premise that this is a natural and logical path for structural transformation. But upon closer examination, we find that very few countries that export raw materials also export their processed forms, or transition to greater processing. The quantitative analysis finds that broad factor intensities do a much better job of identifying patterns of production and structural transformation than forward linkages, which have an insignificant impact despite the fact that our data is biased against finding significant effects of factor intensities and towards finding significant effects of forward linkages. Moreover, the explanatory power of forward linkages is even smaller in sectors with high transport costs, and in sectors classified as primary products or raw materials, which are the most common targets of such policies. Finally, the results are the same even when only considering developed countries, meaning that colonial legacy inhibiting transitions to natural resource processing are not to blame. These results suggest that policies to promote greater downstream processing as an export promotion policy are misguided. Structural transformation favors sectors with similar technological requirements, factor intensities, and other requisite capabilities, not products connected in production chains. There is no reason for countries like South Africa to focus attention on beneficiation at the expense of policies that would allow other export sectors to emerge. This makes no sense conceptually, and is completely inconsistent with international experience. Quite simply, beneficiation is a bad policy paradigm.

Valuable input for this work was provided by Charles Sabel and Lawrence Edwards.

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Introduction

Vertical relationships in production chains, known as linkages, have had a profound impact on economic policy in developing countries. In particular, policies using forward linkages as a guide to stimulate structural transformation and growth have been very popular. Such policies go by many names, such as promoting downstream processing, completing value chains, increasing value-added, and beneficiation, but they are all based on the same idea: that it is a logical, natural progression for countries exporting raw materials to move into the processing of such materials, and therefore policies encouraging that progression can accelerate growth. In other words, structural transformation is strongly influenced by forward linkage relationships.

For example, in Papua New Guinea, the Minister of Trade and Industry reported that government is “keen to promote downstream processing of raw materials to create value-added products for export and to generate employment” (New York Times Magazine 2006). Fiji’s minister for commerce, investment and business development echoed this desire to actively promote downstream wood processing (Vuetilovoni 2006). The Solomon Islands is another example where forward linkage-based policies have been pursued in the forestry sector, such as “export taxes on unprocessed timber and fish, as well as efforts to make fishing and logging licenses largely conditional upon domestic processing” (WTO 1998). Similarly, the Minister for Lands and Forestry in Ghana championed the “maintenance of log export suspension to promote downstream processing” (AFLEG 2003), which was instituted in 1996[1].

Another sector often targeted with forward linkage-based policies is the mining sector. In South Africa, the National Industrial Policy Framework proclaims “the promotion of beneficiation of raw materials in downstream sectors is a logical progression to complete various value chains in the South African economy” (Department of Trade and Industry, version 12, July 2006, p35). The country has implemented export controls on the export of many unprocessed mineral products, using both export permits and outright bans, as well as financing schemes to promote mineral beneficiation (WTO 2003). Zambia’s fifth national development plan “recognizes the important role of downstream processing of mineral products” and therefore “efforts to integrate the copper mining sub-sector into the Zambian economy by encouraging value addition will be pursued by supporting manufacturing industries using copper and other metals as raw materials” (Republic of Zambia 2005). And in Botswana, the government has pressured its joint-venture with De Beers (Debswana) to actively promote downstream processing, such as diamond cutting and polishing (US Embassy Commercial Guide, 2006). These mining policies aren’t limited to developing countries: in Australia, the government has expressed a keen interest in encouraging downstream processing of uranium (Parliament of Australia 2006).

[1] According to a 2001 study, earnings from processed and semi-processed wood did not increased significantly after this policy was implemented, and earnings from the processed and unprocessed wood sectors combined actually declined (World Bank, 2001).

But what is the basis for such linkage-based policies? Proponents most often point out that physical proximity to raw materials provides downstream processors with advantages because of the transportation costs. Why ship raw cotton from Africa all the way to Europe to be processed when it could be processed locally? This argument becomes even more forceful for natural resources with higher transportation costs, such as logs, and has been formalized in the 'new' economic geography literature. In addition to transportation costs, local supply may be more secure as well as cheaper. It could also be more precisely matched to downstream producer needs.

Whatever the explanation, there is very little empirical work that demonstrates the validity of these views and the policies to which they give rise. Such policies are often justified based on logic, anecdotes, and what is taken as self-evident truth rather than systematic analysis. Empirical work relating to linkages has been focused on developing newer and better techniques for measuring which sectors have the strongest linkages in an economy[2] rather than in establishing any effect of linkages on structural transformation. This is very worrisome, given the prominent role of linkage-based policies in developing countries.

This paper seeks to fill this void. We combine a new methodology to study international patterns of production and the process of structural transformation with a highly disaggregated input-output matrix to consider the empirical relevance of forward linkages to cross-country patterns of trade performance over time.

The main findings are that forward linkages play an extremely small role when compared to traditional determinants of comparative advantage, even though our measures have an inherent bias that should make linkages seem more important and factor intensities less important. Therefore, policies assuming that moving 'downstream' is a natural progression are not supported by international experience. Furthermore, and somewhat paradoxically, the impact of forward linkages is actually weaker among goods with higher transportation costs, meaning the transportation cost savings of local processing of raw materials is not a justification for forward linkage-based policies. Consistent with this finding, we also show that the small impact of forward linkages on production patterns is even weaker from primary raw materials than from other manufactured goods. This is quite important given that most forward linkage-based policies are focused exactly on these sectors, seeking to promote greater processing of natural resources. Finally, we show that the small effect of forward linkages is not due to legacies of colonialism, where developing countries were set up to exploit raw materials with no opportunities for local processing. The small impact of linkages is as true for industrialized countries as it is for developing countries.

In the case of South Africa, these results clearly show that beneficiation is the wrong approach. There is no reason to pay special attention to downstream sectors at the expense of missed opportunities from the entire set of 'lateral' sectors that don't currently exist. The case is actually stronger: not only is such an approach without conceptual

[2] 'Key sector identification', e.g. Hewings et al.1989, Hazari 2001, Diaz et al. 2006)

justification: it is a bet against the whole of international experience. Quite simply, beneficiation is a bad policy paradigm.

Literature Review

Linkages jumped to prominence in development thinking in the 1960s with Hirschman's 'The Strategy of Economic Development'. In a postscript to the 1988 edition, he notes that "if a popularity contest were held for the various propositions I advanced in Strategy, the idea of favoring industries with strong backward and forward linkages would surely receive first prize."

The reason for focusing on linkages stems from the overall philosophy of Strategy: the search for effective 'inducement mechanisms'. Hirschman argued that the problem is not a "lack of one or even of several needed factors or elements (capital, education, etc.) that must be combined with other elements to produce economic development, but with the deficiency in the combining process itself." This deficiency is due to "insufficient number and speed of development decisions and to inadequate performance of developmental tasks" arising from the fundamental characteristics of less-developed countries. The task of economic policy in developing countries is therefore to determine "under what conditions development decisions can be called forth in spite of these imperfections… through inducement mechanisms." Instead deriving policy goals from a clear theoretical model of economic growth, Hirschman held that such models don't apply to developing countries, and development policy was simply a search for those policy levers (inducement mechanisms) that had the highest marginal impact. This approach is consistent with the forward linkage-based policies mentioned above, which are adopted with a view towards inducing sectors which are natural quick-wins: the processing of current raw material exports.

One of the principal inducement mechanisms Hirschman identifies in Strategy is stimulating investments in industries with the greatest backward or forward linkages, because "every nonprimary economic activity will induce attempts to supply through domestic production the inputs needed in that activity" (backward linkages) and "every activity that does not by its nature cater exclusively to final demands will induce attempts to utilize its outputs as inputs in some new activities" (forward linkages). Therefore, inducing investment in a highly linked industry will have a larger total effect through stimulating upstream supply and downstream demand. Although in the absence of transportation costs, free importing of inputs and exporting of output in theory makes domestic linkages unimportant, Hirschman held that in practice, domestic availability is at a premium because 1) the special skills needed to import are rare, 2) imported inputs are exposed to currency movements, and 3) domestic input suppliers are more likely to invest in downstream activities within their own country given a home-country bias in investment decisions.

The intuitive appeal of these arguments led to their rapid adoption in policy circles, particularly in Latin America, leading to two popular policy ideas based on linkages. The first is import-substituting industrialization (ISI), which sought to induce investment, structural transformation, and economic growth through “final demand linkage” (Hirschman). “ISI starts predominantly with the manufacture of finished consumer goods that were previously imported and then moves on, more or less rapidly and successfully, to the higher stages of manufacture, that is, to intermediate goods and machinery, through backward linkage effects” (Hirschman 1968). Governments restrict imports of these finished consumer goods to set up “last industries first”, which then would create domestic demand for the required inputs and “maximize the impact of backward linkages and achieve rapid industrialization and overall economic growth” (Kelegama & Foley 1999). Tariff structures with so-called tariff escalation in which final goods have higher tariffs than semi-finished goods and raw material reflect this approach.

The second popular policy idea based on linkages is encouraging greater downstream processing of primary products that were previously exported as raw materials. This is attempted by increasing barriers to exporting goods in one part of the value chain in order to stimulate the creation of downstream industries.

Backward linkage-based policies such as ISI have largely been abandoned. These policies were often part of a larger package that included a reliance on central planning, quotas and exchange controls, overvalued exchange rates, and wage rigidity (Bruton 1998), a mix that led to stagnation and macroeconomic crises. Yet many policies based on forward linkages remain quite popular, as presented in the introduction.

Until recently, the prominent role for linkages was despite the lack of clear theoretical foundations, a shortcoming which was previously noted. Critics argued that policies seeking to induce investments based on the expected benefits of linkages failed were misguided, as the relevant dimension was comparative advantage from factor endowments and technological differences (Reidel 1976). Without any clear definition of a market failure, Hirschman’s linkages are “are of no particular economic significance” (Puga and Venables 1999). Moreover, “participation in international trade provides an economy with the opportunity to specialize in products in which it has comparative advantage… while relying on trade for the procurement of inputs” (Kelegama & Foley 1999), meaning that even if linkages matter in autarky, as trade costs fall they should matter less. This view is consistent with evidence that vertical specialization[3] has grown significantly over the past 20 years (Yi 2003).

Theoretical clarity was brought to the role of linkages by the new economic geography literature (see Ottaviano & Puga 1998 for a review). This work models the location decisions of firms and derives the resulting spatial and industrial structures of nations, seeking to explain why agglomeration may occur in different areas within countries as well as across countries. Most relevant is the model of Venables (1996), which focused on vertical input-output linkages and transport costs, and required no labor mobility nor technological externalities to explain international patterns of production. According to this model, “if vertical linkages are strong and trade costs remain substantial then

[3] “The increasing interconnectedness of production processes in a sequential, vertical trading chain stretching across many countries, with each country specializing in particular stages of a good’s production sequence” Yi 2003

economic integration may lead to clustering in a single location. If linkages are weaker and transport costs are small then integration may lead to dispersion as firms relocate in response to wage differences" (Venables 1996).

This dependency of the effect on linkages on transportation costs is a key feature that allows us to test this theoretical basis for forward-linkage based policies. Not only is Venables' model the principal "formalization of Hirschman-type 'forward' and 'backward' linkages" (Ottaviano & Puga 1998), but it is also an influential model in the analysis of cross-country agglomeration when labor is not freely mobile (Krugman 1998). Therefore, our analysis of linkages' role in international patterns of production is not only relevant to forward linkage-based policies, but also speaks to the new economic geography literature.

Methodology

In order to evaluate the relationship between forward linkages and structural transformation, and compare it to the effect of factor intensities, we first motivate measurements for these three variables.

Measuring Structural Transformation

Our goal is to evaluate what role forward linkages play in determining international patterns of production specialization and how they change over time, a process often referred to as structural transformation. In Hausmann & Klinger (2007) we develop a measure of the revealed proximity of every pair of products, which captures the degree to which products are produced in tandem. This is simply the probability of jointly exporting both products.

It is important to note that we are using export data and not domestic production data. This is for a variety of reasons. First, only export data is available internationally at a high level of desegregation by product. Second, while inefficient domestic production could continue indefinitely in the presence of protection, exporting is more likely to reveal actual productive and efficient production, as international standards have to be met at competitive prices and according to the rules of international trade. Therefore, using export data is closer to measuring true structural transformation.

As discussed in Hausmann & Klinger (2007), the appropriate metric for joint exporting is not the joint probability, but the conditional probabilities of exporting both goods with comparative advantage. In Hausmann & Klinger (2007) we take the minimum of the pairwise conditional probabilities in order to have a symmetric distance measure that can be graphically mapped. Here, as we are interested in the direction of linkage relationships, we will use the asymmetric measure of proximity. Our first measure of structural transformation, which is the probability of joint exporting, is therefore

$$A_t \rightarrow B_t = P\left(X_{B,t} \mid X_{A,t}\right)$$

where X is defined as having revealed comparative advantage in exports.

This probability of joint exporting measured internationally has been shown to influence subsequent structural transformation within countries over time (Hausmann & Klinger 2007). But as a robustness check we will also measure the probability of these transitions directly, as our second measure of structural transformation. This allows for the possibility that the transition from one product to another through linkages happens in such a way that both aren't exported contemporaneously.

$$A_t \rightarrow B_{t+j} = P\left(X_{B,t+j} \mid X_{A,t} \cap \overline{X}_{B,t}\right)$$

We aggregate the Feenstra et al. (2004) World Trade Flows data, which is in the SITCr2 4-digit coding system, to the NAICS classification system used in the input-output tables, which will be used to measure linkages. The concordance was graciously provided by Nathan Nunn. This gives a total of 241 products, with export values from 1975-2000 for all countries. For each pair of products, our metrics of joint exporting and of transitions allow us to study what are the relationships between pairs of products that make them exported by the same country, or allow countries to more frequently transition from one to the other.

Measuring Linkages

The dependent variable of interest is forward linkages, which is the degree to which the output of one sector is the input for another. These are measured using the United States 1997 input output (IO) table. Unlike the majority of input-output tables available internationally, this table is highly disaggregated at the product level, providing 241 NAICS industries that match up to export data. Although it would be preferable to have a separate IO table for each country, numerous studies have shown that the cross-country differences in input-output relationships are minor, even when comparing developing with developed countries (Chenery & Watanabe 1958, Simpson & Tsukui 1965, Santhanam & Patil 1972). The amount of logs used in sawmills or leather used is shoes does not change significantly from country to country, and therefore, the US IO matrix is a valid approximation of worldwide production technology.

We use the industry input-output table that includes both direct and indirect linkages (the Leontief inverse). Although early work on linkages used the direct input-output coefficient (Chenery & Wantanabe 1958), the literature converged to the indirect linkage value as the appropriate measure (Rasmussen 1956), which Hirschman himself referred to as a more 'refined measure'. The Leontief inverse captures both direct and indirect relationships. For example steel is used directly in cars, but also indirectly in cars as it is used to make machines that make cars. The Leontief inverse captures both the direct and indirect use of steel. "The total requirements table [Leontief inverse] recognizes that an increase in demand for a sector's output has a greater impact on the economy than the direct effect. Industries that supply inputs to the sector experiencing the increase in demand must also increase their purchase of inputs for their production" (Temurshoev 2004).

Some have questioned the validity of using the Leontief inverse matrix for measuring forward linkages. The interpretation of the coefficient as a backward linkage is 'if production in this industry rises by $1, what happens to demand faced by its suppliers, directly and indirectly, in dollars'. For forward linkages, the interpretation is less straightforward: 'if production in every single industry using this industry as an input rises by $1 what happens to demand for this industry.' The alternative most often used is the Ghoshian price model (Ghosh 1958), although this model is also disputed as a measure of forward linkages (Oosterhaven 1996). The validity of the Ghosh coefficient versus the Leontief coefficient centers around aggregating to a single measure of the amount of forward linkage from a sector to the economy as a whole. Here, we are using the pairwise coefficients directly and not aggregating for the industry as a whole. For illustrative reasons we standardize the linkage variable by subtracting the mean and dividing by the standard deviation. This is our measure of the degree of forward linkage between two sectors (FL_{AB}).

We drop own industry linkage, as the dependent variable has no meaning when A=B. This would be more problematic if the input-output data were highly aggregated. However, as we have 241 sectors, there remain extremely strong linkages between industries at this level. Moreover, higher levels of desegregation are not necessarily better. For the purposes of evaluating policies using linkages to foster structural transformation, the appropriate level of disaggregation is the same one used by policy makers when they conceive of forward linkage-based policies. According to the statements above, our 241 sector desegregation seems quite appropriate, as it is fine enough to separate raw logs from cut wood or furniture, and iron ore from steel.

Measuring Factor Intensities

The alternative hypothesis to linkages is that factor intensities and technology, the workhorses of traditional trade theory, are the real determinants of structural transformation. Joint exporting of products, and the transitioning from one product to another, would be determined by factor intensities and comparative advantage.

We include two categorical measures of factor intensities common in the literature: the Leamer commodity groupings (Leamer 1984) to capture factor intensities, and the Lall (2000) categories of technological sophistication. As the probabilities of joint exporting and of transitions are for pairs of products, the Leamer and Lall categorical variables are captured as follows:

> *LALL* = 1 if A and B are in the same technological class, 0 otherwise.
> *LEAMER* = 1 if A and B are in the same Leamer commodity group, 0 otherwise.

Some may consider these categorical variables too crude groupings to capture factor endowments, so we also use continuous measures of similarities in intensity of labor (*L*), human capital (*H*), and physical capital (*K*). L_A and K_A are labor's share and capital's share in industry *A*'s total value added, respectively, taken from the same input output table as the linkage variable, and multiplied by 100 for illustrative purposes. H_A is measured as the average wage in industry *A* in thousands of US dollars, taken from the United States economic census. As the unit of analysis is pairs of products, we define the independent variable L_{AB} as the absolute value of the difference between L_A and L_B, with K_{AB} and H_{AB} similarly defined. These differences are standardized by subtracting the mean and dividing by the standard deviation to make the coefficients in comparable units. When these differences are large, industries *A* and *B* have dissimilar factor requirements and therefore should be exported less often from the same country. The expected relationship between proximity and these variables is therefore negative.

Although using the US IO table to measure international input-output linkages is valid, it may be more problematic to use that table to measure factor intensities. Factor mixes are likely to vary quite a bit across countries given the factor price differentials observed (particularly for *L* and *H*). While the amount of leather used in shoes and logs used in wood does not change much between countries, the amount of labor versus capital used in the production of wood or shoes does change, with developed countries using more automation (capital) and fewer workers. Therefore, these measures of factor intensities are a lower bound of the impact of comparative advantage on patterns of production internationally, and our estimation is therefore biased against finding significant impacts of factor intensities compared to IO linkages.

Results

To get a sense of the data, we first look directly at four sectors commonly associated with forward linkage-based policies: Cotton, Sugar, Wood (logs), and Precious Metals. For each of these sectors we first show their three 'downstream' sectors. These are the sectors with the highest forward linkage from the natural resource. For example, the closest downstream sector to Cotton is Other Oilseed Processing (cotton processing), as well as fiber, yarn, and thread mills and fabric mills. These three industries use a great deal of raw cotton as an input, and according to a forward linkage-based view of the world, many countries that are good at exporting raw cotton should also be good at exporting processed cotton, yarns, and fabrics. This means that the probability of joint exporting ($A_t \rightarrow B_t$) should be high. Furthermore, of those countries that export raw cotton but don't export processed cotton, yarns, and fabrics, we should see that over time, many of them follow the 'natural' progression into these sectors from raw cotton. That is, the probability of transitioning ($A_t \rightarrow B_{t+5}$) should be high.

In addition to providing data on the three main downstream industries, we also provide data on the ten closest industries. These are the sectors with the highest probability of being exported by countries that also export raw cotton: they have a high probability of joint export ($A_t \rightarrow B_t$). A forward linkage-based view of the world suggests that the closest industries to a raw material should be the downstream processed material.

Table 1: Cotton

Industry A: Cotton (111920); 29 Exporters in 1995; L_A = 8.3 ; K_A = 25.3; H_A = .

Downstream Industries

Industry B	FL_{AB}	A→B	A_t→B_{t+5}	L_B	K_B	H_B
Other oilseed processing	27.12	24	9	6	2	34
Fiber, yarn, and thread mills	13.95	26	5	18	2	26
Broadwoven fabric mills	8.69	13	7	23	3	28

The 10 'Closest' Industries

Industry B	FL_{AB}	A→B	A_t→B_{t+5}	L_B	K_B	H_B
All other crop farming	-0.15	55	15	5	38	
Fruit farming	-0.11	50	26	19	28	
Fishing	-0.16	47	18	12	45	
Animal, except poultry, slaughtering	-0.09	45	9	8	1	27
Coffee and tea manufacturing	-0.16	42	0	7	6	42
Vegetable and melon farming	-0.14	42	30	13	46	
Jewelry and silverware manufacturing	-0.19	39	15	22	9	31
Other miscellaneous textile product mills	1.83	39	8	27	6	25
Sugar manufacturing	-0.17	37	14	10	4	39
Sawmills	-0.13	34	7	16	6	33

Table 2: Sugar

Industry A: Sugar Manufacturers (311310); 30 Exporters in 1995; L_A = 10.4 ; K_A = 4.1; H_A = 38.5

Downstream Industries

Industry B	FL_{AB}	A→B	A_t→B_{t+5}	L_B	K_B	H_B
Nonchocolate confectionery manufacturing	7.11	32	3	18	30	33
Confectionery manufacturing from cacao beans	6.94	16	4	14	21	44
Breakfast cereal manufacturing	4.35	16	7	10	9	54

The 10 'Closest' Industries

Industry B	FL_{AB}	A→B	A_t→B_{t+5}	L_B	K_B	H_B
Cut and sew apparel manufacturing	-0.19	65	25	22	14	21
Fishing	-0.18	65	33	12	45	
All other crop farming	-0.19	52	22	5	38	
Coffee and tea manufacturing	-0.19	48	6	7	6	42
Spice and extract manufacturing	1.34	48	5	14	33	43
Fruit farming	-0.19	48	31	19	28	
Cotton farming	-0.18	45	20	8	25	
Other nonmetallic mineral mining	-0.19	42	9	21	25	43
Forest nurseries, forest products, timber tracts	-0.15	42	5	2	37	
Vegetable and melon farming	-0.19	42	26	13	46	

Table 3: Logs

Industry A: Logs (113300); 25 Exporters in 1995; L_A = 13.3 ; K_A = 36.6; H_A = .

Downstream Industries

Industry B	FL_{AB}	A→B	A_t→B_{t+5}	L_B	K_B	H_B
Sawmills	41.35	64	33	16	6	33
Veneer and plywood manufacturing	36.41	32	11	21	4	36
Pulp mills	20.48	32	8	21	5	61

The 10 'Closest' Industries

Industry B	FL_{AB}	A→B	A_t→B_{t+5}	L_B	K_B	H_B
Sawmills	41.35	64	33	16	6	33
Fruit farming	0.26	52	17	19	28	
Flour milling	-0.04	44	14	7	9	39
Fishing	0.01	44	13	12	45	
Confectionery manufacturing from cacao beans	0.08	40	8	14	21	44
Cotton farming	-0.06	36	8	8	25	
Seafood product preparation and packaging	0.06	36	9	16	0	26
Other basic inorganic chemical manufacturing	-0.06	36	8	16	24	60
Reconstituted wood product manufacturing	12.52	36	0	19	16	34
Animal production (except cattle poultry and eggs)	-0.03	36	0	6	3	

Table 4: Precious Metals

Industry A: Gold, silver, other ore mining (2122A0); 24 Exporters in 1995; L_A = 26 ; K_A = 16.4; H_A = 57

Downstream Industries

Industry B	FL_{AB}	A→B	A_t→B_{t+5}	L_B	K_B	H_B
Primary nonferrous metal, except copper/aluminum	11.78	25	6	15	0	48
Copper, nickel, lead, and zinc mining	2.15	29	0	19	21	46
Jewelry and silverware manufacturing	1.53	38	17	22	9	31

The 10 'Closest' Industries

Industry B	FL_{AB}	A→B	A_t→B_{t+5}	L_B	K_B	H_B
Fishing	-0.19	54	17	12	45	
Coffee and tea manufacturing	-0.18	46	14	7	6	42
Fruit farming	-0.18	42	20	19	28	
Animal, except poultry, slaughtering	-0.17	42	6	8	1	27
Jewelry and silverware manufacturing	1.53	38	17	22	9	31
Other nonmetallic mineral mining	-0.15	38	16	21	25	43
Cut and sew apparel manufacturing	-0.17	38	5	22	14	21
All other crop farming	-0.14	38	29	5	38	
Cotton farming	-0.16	38	14	8	25	
Fiber, yarn, and thread mills	-0.17	38	6	18	2	26

In the case of cotton, we see that only 24% or raw cotton exporters also export processed cotton. Furthermore, of the countries that exported raw cotton in 1995 but did not export processed cotton, only 9% were able to gain comparative advantage in processed cotton over the next 5 years. At the same time, 50% of raw cotton exporters also export fruit, and 42% also export coffee. And one quarter of raw cotton exporters who could not export fruit with comparative advantage in 1995 were able to develop comparative advantage in the fruit sector over the next 5 years. Forward linkages don't seem to be strongly linked to either joint exporting or transitions.

The same is found for raw sugar exporters. Only one third of raw sugar exporters also export that natural resource's downstream industry: confectionary products. But two thirds export manufactured apparel. Only 3% of raw sugar exporters who did not export confectionary products in 1995 were able to discover that sector by 2000, whereas the percentage of transitions from sugar to garments was 30%. One-quarter of raw gold and silver exporters also export those metals in more processed forms, and one third also export jewelry and silverware. The same proportion also export raw cotton, apparel, and other minerals, whereas over half also export fish.

The image emerging from these tables is that less than one-third of raw material exporters in these three sectors also export the next downstream product. Instead of following forward linages, we see that countries that are good at exporting a raw natural resource like cotton are also good at exporting another raw natural resource like coffee, as well as a simple manufacture like garments, and not often a more complex manufacture like breakfast cereals.

One interesting case is the logging sector (Table 3). We see that more than half of the world's log exporters also export sawmill output, and it was common to see countries that exported logs but not mill output in 1995 transition to export mill output by 2000. In the introduction, we saw that many log exporters in developing countries have explicit policies preventing raw log exports in order to stimulate downstream industries. This is an illustration of what is likely a significant bias in our data: policy bias. We are trying to measure natural economic relationships in a distortion-free equilibrium, but when using real-world export data our measures incorporate the effects of real-world policies. Given the numerous policies to promote wood processing, we will observe more raw log exporters also exporting processed wood than in a distortion-free equilibrium, without these policies. So the policy bias makes our measures of distance (both joint exporting and transitions) overestimates of the true economic relationships between sectors and their downstream counterparts. Nevertheless, even with this policy bias, we see that more log exporters exported fruit than plywood.

We can also see in these tables that the metrics of factor intensities seem to explain some of the emerging relationships between products. For example, production and export of logs is relatively intensive in capital and un-intensive in labor, whereas pulp mills are the opposite. And the data show that it is more common to see log exporters also export fish, which have a similar factor intensity mix, than export pulp mill output. This is consistent with comparative advantage based on factor intensities, as well as the general 'capabilities' view offered in Hausmann and Klinger (2007). What are the capabilities needed to export logs? Probably a mix of natural resource property rights, firms with sufficient capital to harvest the resource, and simple rural infrastructure to gather the resource and ship it to port efficiently and securely. This mix of national-level capabilities seems much more relevant to fish exports than pulp mills, which require centralized factories with armies of unskilled workers that are conditioned for factory work. In order to be successful at growing and exporting raw cotton, a country requires specific climactic conditions (a long frost-free growing season, moderate precipitation, and nutrient-rich soil), as well as the basic infrastructure to export the output (which is not highly sensitive to spoilage), a small amount of labor, and significant capital. This set of capabilities is much more useful for other crops than for mills, which require very little capital and significant amounts of industrially-trained but not highly-skilled laborers. Correspondingly, we see more cotton exporters achieve success at other crops and more log exporters achieve success in fish than we do cotton exporters achieve success in cotton processing mills and log exporters achieve success in wood mills. And the first movements of raw material exporters into the realm of manufacturing is into more simple manufactures like garments, rather than raw material manufacturing.

To test these relationships more carefully, we more to a regression framework and consider the entire set of available data. The basic estimation pits forward linkages against the traditional determinants of production patterns (factor intensities) by estimating the following equation:

$$A_t \rightarrow B_t = \alpha + \beta_1 FL + \beta_2 FACTORS + \gamma_A + \eta_B + \varepsilon_t$$

where *FACTORS* includes *LEAMER*, *LALL*, *L*, *K*, and *H*. As we are interested in the relationship between the products rather than the product's own degree of connectedness to other products, product fixed effects γ_A and η_B are included.

The distance variable has been multiplied by 100 for illustrative purposes. Their summary statistics are:

$A_t \rightarrow B_t$**:** mean=27, standard deviation=19
$A_t \rightarrow B_{t+5}$: mean = 8, standard deviation=12

The results are shown in the following table, first using the joint exporting measure ($A_t \rightarrow B_t$ in columns 1 and 2) and second with the transitions measure ($A_t \rightarrow B_{t+5}$ in columns 3 and 4). Columns 1 and 3 include only the forward linkage variable, while columns 2 and 4 also include the factor intensity variables. All results are for 1995 (results for 1975 to 2000 for $A_t \rightarrow B_t$ and 1975-1995 for $A_t \rightarrow B_{t+5}$ are provided in the Appendix, with all findings discussed below continuing to hold in that data).

Table 5

	(1)	(2)	(3)	(4)
	A->B	A->B	A_t->B_{t+5}	A_t->B_{t+5}
FL	0.837	0.615	0.246	0.241
	(20.41)**	(10.80)**	(8.17)**	(5.41)**
LEAMER		4.951		1.387
		(25.98)**		(9.30)**
LALL		3.422		0.648
		(16.79)**		(4.07)**
L_{AB}		-1.528		-0.537
		(19.70)**		(8.85)**
K_{AB}		-0.151		-0.077
		(1.70)		(1.11)
H_{AB}		-2.073		-0.355
		(26.41)**		(5.78)**
Constant	10.243	35.923	5.845	8.179
	(8.70)**	(29.35)**	(6.75)**	(8.54)**
Observations	51810	43070	51810	43070
R-squared	0.40	0.46	0.26	0.28

Absolute value of t statistics in parentheses
* significant at 5%; ** significant at 1%

The results shown in this table are consistent with the observations in tables 1 through 4: the impact of linkages on patterns of production is very small in comparison to the effects of broad factor intensities. Forward linkages have statistically significant relationship with distance, but not an economically significant relationship. Going from the 1st percentile in forward linkage strength (-0.197, from footwear manufacturing to stationary and related manufacturing) to the 99th percentile in forward linkage strength (3.13, from leather products to footwear) has an effect on distance of only 2, which is barely 1/10th of one standard deviation. Compare this to the impact of the pair of products having the same broad factor intensities (*LEAMER*) or technological sophistication (*LALL*), which have a relationship with (contemporaneous) distance of 5 and 3.4, respectively, or similar human capital requirements, where a 3 standard deviation increase similarity is associated with an increase in distance of 6. The same relative results hold when using the measure of transitions in columns 3 and 4.

Furthermore, it is important to note that the *FACTOR* metrics are closely related and likely colinear. In addition, as discussed in the methodology section, these are a lower-bound on the impact of factor intensities. The impact of the factor intensity variables is biased downward because it is a very noisy measure of international factor intensities, whereas the impact of linkages are biased upward because of policy bias. It is also interesting to note that all of our measures of factor intensities are significant, with the exception of *K*. This is consistent with the intuition that capital is the most internationally mobile factor and therefore the least important in determining international patterns of production.

Heterogeneous Linkage Effects: Transportation costs and Natural Resources

Forward linkage-based policies are often based on the following logic: shipping raw materials to a third country for processing before export to the final user of the processed good is not sensible, as it imposes additional transportation costs. If the source country of the raw materials were able to process them locally and export directly, they would have a cost advantage, as they could avoid these additional transportation costs. This argument is formalized in Venables' model of agglomeration, and suggests that linkages will matter more for products with higher transport costs. When transport costs are low, production can disperse to countries with the lowest factor costs more easily, whereas if transport costs are high, there is a greater benefit to co-location[4].

This can be tested directly with an industry level measure of transport costs. This is taken as the difference between CIF price, which is the cost inclusive of insurance and freight, and FOB (free on board), as a percentage of FOB, from US import data. This figure is the percentage of the production costs of the sector that must spent on transportation for US imports. For example, 33% of the FOB cost of coal mining goes towards transportation costs, 24% of the cost of cement manufacturing, 9% of the cost of beer, 2% of the cost of semiconductors, and 0.3% of the cost of aircraft. This includes not only transport costs but also insurance and tariff costs. Yet it makes sense to include these other costs with transportation costs, as the goal is to capture the cost savings from producing the input or output in the same country rather than importing or exporting it.

The estimation is therefore

$$A_t \to B_t = \alpha + \beta_1 FL + \beta_2 T_{AB} + \beta_3 T_{AB} FL + \gamma_A + \eta_B + \varepsilon_t$$

T_{AB} is the transport cost for good A multiplied by the transport costs for good B (only the interaction has to be included, as each product's own transportation costs are captured by γ_A and η_B), and has been standardized in the same manner as the linkage variable. $T_{AB}FL$ is therefore the variable of interest. If linkages matter more for products with higher transportation costs, then this term should be positive. The results are shown below.

[4] At the extreme, when transport costs are very high, agglomeration reverses as all production must take place next to markets.

Table 6

	(1)	(2)
	A->B	A_t->B_{t+5}
FL	0.589	0.237
	(10.10)**	(5.16)**
LEAMER	4.692	1.288
	(23.67)**	(8.26)**
LALL	3.104	0.575
	(14.79)**	(3.48)**
L_{AB}	-1.623	-0.566
	(19.96)**	(8.85)**
K_{AB}	-0.109	-0.068
	(1.17)	(0.92)
H_{AB}	-2.201	-0.411
	(26.90)**	(6.39)**
T_{AB}	1.939	0.663
	(15.79)**	(6.86)**
T_{AB}FL	-0.232	-0.092
	(3.86)**	(1.95)
Constant	-6.361	-4.137
	(4.27)**	(3.53)**
Observations	40605	40605
R-squared	0.46	0.28

Absolute value of t statistics in parentheses
* significant at 5%; ** significant at 1%

Not only is the coefficient on $T_{AB}FL$ not positive, it is actually negative and significant! That is, linkages matter *less* in determining international patterns of production among goods with high transportation costs. Why could this be? Transportation costs are indirectly an inverse measure of value to weight and volume. Transportation costs for cement are high because a cubic foot or a pound of cement is cheap, whereas a cubit foot or a pound of semiconductors are expensive, and therefore transportation costs as a percentage of value are higher for cement than semiconductors (because transportation costs are determined by size and weight). Therefore, forward linkages would matter more for goods with lower transportation costs if these high value to weight/volume products have another characteristic, such as high technological complexity, which makes forward linkages more important for structural transformation. For example, forward linkages may capture the similarity in technological knowledge required for semiconductors (upstream) and computers (downstream) than for cotton (upstream) and manufactured yarn (downstream).

This finding has important implications for economic theory, as Venables' model of agglomeration is inconsistent with the empirical evidence. But more importantly, it has important implications for policy. It discounts the motivation for forward linkage-based policies of saving transportation costs by processing locally.

One might argue that the full data, which is mostly comprised of manufactures, is washing out the effects of forward linkages connecting raw materials with downstream processing in some other way. We can consider the merits of forward linkage-based policies even more directly by splitting the sample. Leamer has a category of 'raw materials', and Lall has a category of 'primary products' (which are largely overlapping, but not completely). Below we show the basic estimation, first Leamer's 'raw materials' compared to all other products, and then for Lall's 'primary products' compared to all other products.

Table 7

	Leamer's 'Raw Materials'	Non-Raw Materials	Lall's 'Primary Products'	Non-Primary Products
	A->B	A->B	A->B	A->B
FL	0.532	0.908	0.620	0.953
	(6.19)**	(13.20)**	(8.37)**	(13.00)**
L_{AB}	0.465	-2.177	-0.867	-1.766
	(2.12)*	(26.72)**	(4.95)**	(19.73)**
K_{AB}	0.253	-0.283	-0.007	-0.217
	(1.30)	(2.90)**	(0.05)	(2.10)*
H_{AB}	-0.304	-2.505	-1.095	-2.563
	(1.08)	(29.70)**	(6.62)**	(29.29)**
Constant	34.522	7.600	16.867	14.198
	(13.39)**	(5.62)**	(9.11)**	(0.00)
Observations	3851	39219	6815	36255
R-squared	0.59	0.44	0.56	0.43

Absolute value of t statistics in parentheses
* significant at 5%; ** significant at 1%

Both with the Leamer category and the Lall category most often associated with forward linkage-based policies, the coefficient on forward linkages is *smaller* than that for manufactures, and this difference is statistically significant. Consistent with the finding that production of products with higher transport costs are less responsive to linkages, raw materials are actually less often exported by the same countries that export their downstream processed versions. This result continues to hold when using the transitions measure of structural transformation.

Finally, forward linkage-based policies are often discussed in the context of colonial legacy (e.g. Financial Times 2005). Many colonies in Africa, Latin America, and Asia were established because of their abundant and unexploited natural resources, and the early infrastructure and institutions in these areas was established to simply extract the raw natural resources and send them to the colonizer's home country, or a third country, for processing. It could therefore be the case that the process of moving to downstream processing is inhibited by this colonial legacy, which would imply that our data will be biased against finding such transitions even though they are sensible in a frictionless economic environment. Proponents of forward linkage-based policies often evoke such arguments, presenting such policies as a way to overcome the distortion in this legacy and 'capture' more of the value of the country's natural resources. In the words of South African foreign minister Nkosazana Dlamini-Zuma, a history of "deliberate enslavement and colonial plunder" requires that "Africa shift from being an exporter of resources to an exporter of value-added goods" (Financial Times 2005).

We can consider this possibility by examining the impact of forward linkages on patterns of production exclusively among those countries that don't have this legacy. To do this, we re-calculate our measures of the probability of joint exporting and of transitions using only industrialized countries, and repeat the analysis conducted above. If it is the case that moving downstream is inhibited by colonial legacy, then forward linkages should be significant determinants of joint exporting and of transitions downstream among countries not suffering this legacy. That is, the coefficient on forward linkages should be larger, and have an economically significant impact when compared to factor intensities.

Table 8

	1995	1995	1995	1995
	AAT	AAT	AATt	AATt
FL	1.093	0.770	0.150	0.016
	(17.52)**	(9.08)**	(3.06)**	(0.22)
LEAMER		6.921		0.972
		(26.53)**		(4.56)**
LALL		2.830		0.928
		(10.19)**		(4.09)**
L		-3.158		-0.184
		(29.52)**		(2.11)*
K		-0.364		-0.179
		(2.96)**		(1.77)
H		-2.807		-0.247
		(25.18)**		(2.71)**
Constant	14.831	47.806	6.081	-1.807
	(8.58)**	(26.59)**	(4.48)**	(1.23)
Observations	61752	52212	61752	52212
R-squared	0.44	0.48	0.32	0.33

Absolute value of t statistics in parentheses
* significant at 5%; ** significant at 1%

Table 8 shows that, although there is no doubt that colonial legacy has a profound effect on the process of economic growth, it does not imply that beneficiation policies are sensible. Even when limiting attention to developed countries with no colonial legacy, patterns of production are not associated with forward linkages in a significant way. Although the probability of joint exporting along vertical linkage lines is slightly higher among developed countries, it is not economically significant. Moreover, the probability of transitions following vertical production relationships is even smaller among industrialized countries. Therefore, colonial legacy is not driving our findings.

Conclusion

Beneficiation, moving downstream, and promoting greater value added are very common policy initiatives in developing countries, particularly among those that export natural resources. These countries are seeking to diversify their output away from volatile commodities, reduce employment, and help bring about structural transformation in their economies through a well-targeted 'inducement mechanism'. But what is the basis for using forward linkages as a guide for stimulating structural transformation? Most policy documents suggest this is a natural and logical progression that other developed economies followed, and represents the lowest-hanging fruit given the local presence, and therefore low transportation costs, of the raw materials.

But we have shown that a capabilities view of production, where characteristics as simple as broad factor intensities do a much better job of identifying patterns of production and structural transformation than forward linkages. Forward linkages have an extremely small impact on which sectors are likely to emerge as export successes in a country. And this is despite the fact that our data sources are biased against finding significant effects of factor intensities and towards finding significant effects of forward linkages. Moreover, the explanatory power of forward linkages is even smaller in sectors with high transport costs, suggesting that physical proximity of raw material inputs matters little. Similarly, sectors classified as primary products or raw materials, which are the precise targets of most forward linkage-based policies, are even less likely to be exported in the same countries as their processed versions.

These results suggest that policies to promote greater downstream processing are misguided. Structural transformation in exports favors sectors with similar technological requirements, factor intensities, and other requisite capabilities, not products connected in production chains. Government does not have limitless capacities and resources, so a focus on beneficiation is necessarily at the expense of policies that would enable other potential sectors to emerge. The data clearly show that this is a bad tradeoff, as the better opportunities are more often ‘lateral’ than downstream. Quite simply, beneficiation is a bad policy paradigm.

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Appendix

Impact of Linkages Over Time: Contemporaneous Distance

	1975	1980	1985	1990	1995	2000
	A->B	A->B	A->B	A->B	A->B	A->B
FL	0.431	0.475	0.526	0.624	0.615	0.719
	(6.95)**	(6.57)**	(8.97)**	(10.59)**	(10.80)**	(12.83)**
LEAMER	4.855	5.839	5.927	5.503	4.951	5.200
	(23.39)**	(24.13)**	(30.19)**	(27.90)**	(25.98)**	(27.75)**
LALL	2.110	2.603	3.217	3.166	3.422	3.091
	(9.50)**	(10.06)**	(15.32)**	(15.01)**	(16.79)**	(15.42)**
L	-1.355	-1.262	-1.470	-1.793	-1.528	-1.144
	(16.04)**	(12.82)**	(18.40)**	(22.34)**	(19.70)**	(15.00)**
K	-0.107	-0.203	-0.295	-0.284	-0.151	-0.241
	(1.11)	(1.80)	(3.22)**	(3.09)**	(1.70)	(2.75)**
H	-0.773	-0.825	-1.503	-1.663	-2.073	-1.928
	(9.04)**	(8.28)**	(18.57)**	(20.47)**	(26.41)**	(24.97)**
Constant	11.274	13.756	51.797	32.203	35.923	32.825
	(0.00)	(0.90)	(7.16)**	(0.00)	(29.35)**	(27.27)**
Observations	43069	43070	43069	43069	43070	43070
R-squared	0.58	0.48	0.54	0.47	0.46	0.47

Absolute value of t statistics in parentheses
* significant at 5%; ** significant at 1%

Impact of Linkages Over Time: Transitions

	1975	1980	1985	1990	1995
	A_t->B_{t+5}	A_t->B_{t+5}	A_t->B_{t+5}	A_t->B_{t+5}	A_t->B_{t+5}
FL	0.136	0.252	0.241	0.300	0.241
	(3.49)**	(4.67)**	(5.41)**	(7.30)**	(5.41)**
LEAMER	1.519	2.126	1.387	1.051	1.387
	(11.65)**	(11.78)**	(9.30)**	(7.65)**	(9.30)**
LALL	0.937	1.370	0.648	0.700	0.648
	(6.72)**	(7.10)**	(4.07)**	(4.76)**	(4.07)**
L	-0.199	-0.554	-0.537	-0.182	-0.537
	(3.74)**	(7.54)**	(8.85)**	(3.26)**	(8.85)**
K	-0.218	-0.058	-0.077	0.033	-0.077
	(3.59)**	(0.69)	(1.11)	(0.52)	(1.11)
H	-0.313	-0.317	-0.355	-0.567	-0.355
	(5.82)**	(4.27)**	(5.78)**	(10.02)**	(5.78)**
Constant	19.215	-0.645	18.784	1.010	8.179
	(0.00)	(0.06)	(3.42)**	(0.00)	(8.54)**
Observations	43069	43070	43069	43069	43070
R-squared	0.31	0.40	0.28	0.30	0.28

Absolute value of t statistics in parentheses
* significant at 5%; ** significant at 1%